Volume 6D, Number 4 June 1958

Israel. Research Council.

BULLETIN OF THE RESEARCH COUNCIL OF ISRAEL

Section D BOTANY

Bull. Res. Counc. of Israel. D. Bot.

Continuing the activities of the
Palestine Journal of Botany,
Jerusalem and Rehovot Series

The Weizmann Science Press of Israel • Jerusalem • ירושלים • מוסד ויצמן לפרסומים במדעי הטבע ובטכנולוגיה בישראל •

Volume 6D, Number 4 June 1958

BULLETIN OF THE RESEARCH COUNCIL OF ISRAEL

Section D
BOTANY

Bull. Res. Counc. of Israel. D. Bot.

Continuing the activities of the
Palestine Journal of Botany,
Jerusalem and Rehovot Series

The Weizmann Science Press of Israel • Jerusalem ירושלים • מוסד ויצמן לפרסומים במדעי הטבע ובטכנולוגיה בישראל •

Orders in America should be addressed to Interscience Publishers Inc., New York, N. Y., and in England and Europe to Wm. Dawson & Sons, Ltd., Cannon House, Macklin Street, London, W. C. 2, directly or through booksellers.

Annual subscription per section (four issues): IL. 6.000 ($ 6.00, £ 2.20) Single copy IL. 1.500 ($ 1.50, 12s.)

Manuscripts should be addressed: The Editor, The Weizmann Science Press of Israel, P. O. B. 801, Jerusalem, 33 King George Ave. Telephone 62844

NOTICE TO CONTRIBUTORS

Contributors to the *Bulletin of the Research Council of Israel* should conform to the following recommendations of the editors of this journal in preparing manuscripts for the press.

Contributions must be original and should not have been published previously. When a paper has been accepted for publication, the author(s) may not publish it elsewhere unless permission is received from the Editor of this journal.

Papers may be submitted in English and in French.

MANUSCRIPT

General

Papers should be written as concisely as possible. MSS should be typewritten on one side only and double-spaced, with side margins not less than 2.5 cm wide. Pages, including those containing illustrations, references or tables, should be numbered.

The Editor reserves the right to return a MS to the author for retyping or any alterations. Authors should retain copies of their MS.

Spelling

Spelling should be based on the Oxford Dictionary and should be consistent throughout the paper. Geographic and proper names in particular should be checked for approved forms of spelling or transliteration.

Indications

Greek letters should be indicated in a legend preceding the MS, as well as by a pencil note in the margin on first appearance in the text.

When there is any room for confusion of symbols, they should be carefully differentiated, e.g. the letter "I" and the figure "1"; "O" and "0".

Abbreviations

Titles of journals should be abbreviated according to the *World List of Scientific Periodicals.*

Abstract

Every paper must be accompanied by a brief but comprehensive abstract. Although the length of the abstract is left to the discretion of the author, 3% of the total length of the paper is suggested.

References

In Sections A and C, and in Letters to the Editor in all Sections, references are to be cited in the text by number, e.g., ... Taylor[3] ... and are to be arranged in the order of appearance.

In Sections B, D, E, and G, the references are to be cited in the text by the author's name and date of publication in parentheses, e.g., ... (Taylor 1932).... If the author's name is already mentioned in the text, then the year only appears in the parenthesis, e.g., ... found by Taylor (1932).... The references in these Sections are to be arranged in alphabetical order.

In Section F, references are to be cited in the text by number in square brackets, e.g.,... Taylor [3]... and are to be arranged in alphabetical order.

The following form should be used:

3. Taylor, G. I., 1932, *Proc. roy. Soc.*, A138, 41.

Book references should be prepared according to the following form:

4. Jackson, F., 1930, *Thermodynamics*, 4th ed., Wiley, New York

TYPOGRAPHY

In all matters of typography the form adopted in this issue should be followed. Particular attention should be given to position (of symbols, headings, etc.) and type specification.

ILLUSTRATIONS

Illustrations should be sent in a state suitable for direct photographic reproduction. Line drawings should be drawn in large scale with India ink on white drawing paper, bristol board, tracing paper, blue linen, or blue-lined graph paper. If the lettering cannot be drawn neatly by the author, he should indicate it in pencil for the guidance of the draftsman. Possible photographic reduction should be carefully considered when lettering and in other details.

Half-tone photographs should be on glossy contrast paper.

Illustrations should be mounted on separate sheets of paper on which the caption and figure number is typed. Each drawing and photograph should be identified on the back with the author's name and figure number.

The place in which the figure is to appear should be indicated in the margin of the MS.

PROOFS

Authors making revisions in proofs will be required to bear the costs thereof. Proofs should be returned to the Editor within 24 hours, otherwise no responsibility is assumed for the corrections of the author.

REPRINTS

Reprints may be ordered at the time the proof is returned. A table designating the cost of reprints may be obtained on request.

CONTRIBUTION TO THE KNOWLEDGE OF THE *HELMINTHOSPORIUM* FLORA ON GRAMINEAE IN ISRAEL

R. Kenneth

Department of Plant Pathology, Faculty of Agriculture, The Hebrew University, Rehovot

ABSTRACT

The genus *Helminthosporium* Link has been found to be well-represented in Israel on various *Gramineae.* Descriptions of disease symptoms and of morphological features of the following species are given.

H. avenae Eidam (*Pyrenophora avenae* Ito et Kurub.) on wild and cultivated oats, *H. cynodontis* Marignoni on *Cynodon dactylon; H. dictyoides* Drechsl. on *Festuca arundinacea* and *Brachypodium distachyum; H. maydis* Nis. (*Cochliobolus heterostrophus* Drechsl.) on *Zea mays; H. rostratum* Drechsl. on *Sorghum vulgare* var. *sudanense* and *Eragrostis megastachya; H. sacchari* (v. Breda de Haan) Butler on *Cymbopogon citratus; H. sorghicola* Le Febvre et Sherwin on *Sorghum vulgare* var. *sudanense* and *S. halpense; H. tritici-vulgaris* Nis. on *Triticum durum,* and *H. turcicum* Pass. on *Sorghum vulgare* var. *sudanense, S. vulgare, S. halepense* and *Zea mays.*

A key is given for these species and for a few others known in Israel (*H. gramineum* Rabh., *H. teres* Sacc. and *H. sativum* P. K. et B.).

The disease caused by *H. turcicum* on Sudan grass and on corn is both widespread and severe, whereas that caused by *H. maydis* on corn, albeit very destructive, was found in only one instance.

The author can see no justification for the grouping of many of the *Cylindro-Helminthosporia* on cereals and grasses under one species, *Pleospora trichostoma* (Fr.) Ces. et de Not. as had been suggested in 1949 by Wehmeyer.

INTRODUCTION

In the course of studies now being made on diseases of barley in Israel caused by *Helminthosporium teres* Sacc., *H. sativum* P. K. et B. and *H. gramineum* Rabh., the first of which has caused damage of catastrophic proportions here during the last decade, the question has arisen as to whether the genus *Helminthosporium* Link ex Fries is well represented in this area on other graminicolous species. In the summer of 1956, diseases caused by fungi belonging to this genus were found on a number of economically important cereals and pasture grasses as well as on some weeds of this family, thus answering the question in the affirmative. Certain of these caused very serious diseases which strongly affected yields.

Received July 10, 1957.

This article is a preliminary report on diseases caused by species of *Helminthosporium* on cereals and grasses, as research has merely been begun and further studies on cultural characters of the fungi, as well as their pathogenicity still remain to be carried out. Only those fungi which were definitely determined are dealt with in the following pages, and it is intended to write a more detailed report at a later date as results of pathogenicity tests on these and other species become available.

The species described are:

H. avenae Eidam (*Pyrenophora avenae* Ito et Kurubayashi)
H. cynodontis Marignoni
H. dictyoides Drechsl.
H. maydis Nishikado et Miyake (*Cochliobolus heterostrophus* Drechsl.)
H. rostratum Drechsl.
H. sacchari (v. Breda de Haan) Buttler
H. sorghicola LeFebvre et Sherwin
H. tritici-vulgaris Nishikado (*Pyrenophora tritici-vulgaris* Dickson)
H. turcicum Passerini

H. avenae, H. dictyoides and *H. tritici-vulgaris* belong to the sub-genus *Cylindro-Helminthosporium* of Nishikado (1928) which was given genus rank by Ito under the name *Drechslera* (although the genus designation has not been well-received to date). The *Cylindro-Helminthosporia* possess conidia which are approximately cylindric in shape, and commonly germinate from both polar and intercalary cells; their perfect stage, when known, belongs to the genus *Pyrenophora* Fries. All the other above-mentioned species are characterized by fusiform conidia which commonly germinate from the polar cells only; these have been lumped together in the past under the sub-genus *Eu-Helminthosporium* of Nishikado, as it had been considered that their perfect stage when present is *Cochliobolus* Drechsl. (*Ophiobolus* Riess.), which is indeed true in most instances. However, a number of these species, e.g. *H. rostratum* and *H. turcicum* (which possess protruding hila) lately have been induced by Luttrell (1957) to give rise to a different perfect stage, *Metasphaeria* Sacc. It is logical to add another sub-genus to *Helminthosporium* in which to place these species, as they clearly do not belong to the *Eu-Helminthosporia.*

MATERIALS AND METHODS

Material from the field — either stricken leaves, or in certain cases weathered straw — were placed in damp chambers to induce sporulation. The habit assumed by the fungus on this natural substrate was then studied under the microscope; conidia and conidiophores were then scraped off onto microscope slides where they were examined for various morphological features.

Measurements were made in tap water, using a minimum of 25 and up to 100 conidia per isolate. An attempt was made to study the same isolate under various

conditions of temperature, media, etc., and to compare a number of isolates in order to test the variability of the species. Germination in tap water on microscope slides was observed and conidial cultures were made on Petri-dishes containing potato-dextrose-agar (PDA — 200g potatoes, 20g glucose and 17g agar-agar to 1000 ml tap water). The resulting colonies were examined for any consistent characters which might be of value in identifying the species, e.g. mycelial colour, texture, degree of production of conidia and fruiting bodies, secretion of dyes, etc.

The writer leaned heavily on the excellent monograph of Drechsler (1923) and the recent textbook of Sprague (1950), and found Luttrell's key (1951) and criticism (1954) a valuable adjunct in determining the fungi. Aside from articles treating particular species, other sources were Dickson (1956), Anderson (1954), and Wollenweber (1932). The monograph by Putterill (1954) was not available during the writing of this paper; it was found though to be of great interest and in many cases confirmed the findings below.

ENUMERATION

Helminthosporium avenae Eidam (1891)

Perfect stage: *Pyrenophora avenae* Ito et Kurubayashi (1931).
Found on: *Avena sterilis* L., on leaves and straw, Jerusalem, 29/XII/56; Kiriyat Gat, 24/II/57; Neve Ya'ar, 2/II/57.
Found on *A. sativa L.* (Mulga), on leaves and straw; Tekuma, 24/I/57.

This fungus is found on diseased oat leaves. The symptoms are rather variable, but usually consist of a reddening or yellowing of the leaves (which is commonly associated with many disturbances of oats other than those caused by *H. avenae*) and accompanied by the appearance of short linear blotches which are always few in number. There is generally a withering of the stricken leaves, followed by desiccation, starting from the tip and proceeding downwards.

The fungus sporulates prodigiously on oat stubble at the onset of the winter rains, and a veritable forest of conidiophores and numerous perithecia are to be seen, in particular close to the lower joints of the culm and at the base of the standing straw. Loose straw lying on the ground may be entirely covered with conidiophores.

Description of the fungus

Conidiophores: arising singly or in groups of two or three from the tissue, very dark brown to greenish-black; stalwart, geniculated near the apex, with many scars from the conidia which are grouped close to the tip; up to 12-septate, often 6-8, with septa usually averaging 55μ apart; basal cell expanded often to width of 21μ; may reach $400\text{-}660\mu$ in length; width $7.7\text{-}11.2\mu$.

Conidia (Figure 1): cylindric, straight, outline often uneven; peripheral wall usually thin, sometimes constricted at septa; colour: variable — sub-hyaline to greenish fuligenous to olivaceous; hilum: within contour of peripheral wall, wide, dark (usually reddish brown), conspicuous. Together with hilum the basal cell often resembles a match head; septa: maximum of 8, with 4-6 predominating. Some septa may be oblique; germination: from polar and intermediate cells; catenulation of conidia seen, but rarely; spore measurements: $47\text{-}147\mu \times 9.8\text{-}19.6\mu$ (21.7μ). There was a noticeable difference in spore dimensions among isolates, parti-

cularly with regard to maximum length and minimum and maximum width; conidia from straw from Tekuma were never longer than 73.5μ nor wider than 14.8μ, and the minimum width of 9.8μ was considerably less than in other isolates; in leaves from the same place, however, minimum width was 12.6μ, and when the same straw was put in a damp chamber again some months later, conidia were produced which reached a length of 105μ and a width of 11.2-18.2μ.

Perithecia: on straw culms and sheaths. They are often inverted pear-shaped at maturity (Figure 2); very dark brown to black; 740μ wide × 820μ high.

The perithecia break through the epidermis of straw and remain erumpent; ostiole is undeveloped; setae are always present (Figure 2) and numerous; they are long, straight, slightly tapered toward apex and dark greyish black with a lighter colour near tip.

Conidiophores are produced at times on fruiting bodies; they differ from setae in their browner colour, greater length and thickness and lack of tapering; they may bear conidial scars and conidia and are not as straight as setae.

Asci (Figure 2 and 3): short stipitate with double wall enclosing up to 8 ascospores of all degrees of maturity within a single fruiting body. 224-385μ × 28-38.5μ.

Ascospores (Figure 3): muriform, with 5 transverse septa; greatly constricted at septa; one longitudinal septum extends partway through in mature spores; colour is yellow; germination is from all cells. 40.2-52.5μ × 14.7-21.7μ.

Pycnidia: on straw culms and sheaths; tan, thin-walled, ostiolate; circular outline from above. In culture they are frequently encountered and are tan to light brown, thin-walled, ostiolate, 70-122μ in diameter. Pycnospores exude a sticky mass, are hyaline, continuous, variable in size and shape, — being ellipsoid to elongate but not globose; they are mostly straight, 1.8-3.8 × 1-2.2μ (mostly 3.5 × 1.8μ); they failed to germinate on PDA and on tap water agar.

Discussion

To judge from the data given here, the length of conidia is not a good determinant of species as far as *H. avenae* is concerned, unless perhaps many isolates are used; one isolate (from Jerusalem) on wild oat leaves had a maximum spore length of 147μ, which was not uncommon, and a minimum of 80.5μ, which happens to be the maximum length of the Mulga oat leaf isolate from Tekuma. Spores from wild oat straw from Jerusalem, however, had a maximum length of 105μ, which agree with measurements of the Mulga oat leaf isolate and the Mulga straw isolate when they were induced to produce conidia again in a damp chamber months later. Other measurements as well have convinced the writer that he is dealing with a fungus that displays wide variation in size, even when spores are taken from the same material at different times. In colour too there may be much variation in mature spores, even from the same isolate.

Morphologically, *H. avenae* differs little from *H. teres* as far as conidial characters are concerned, as constrictions at the basal septum may or not be seen in either of the species if enough isolates are examined. Colour of conidia is also a very variable character in Israel with both these species. With regard to length of conidia, it is rather risky to separate the two in this manner, as very short spores may be common in some *H. teres* isolates at times. Nevertheless, those isolates of *H. avenae* examined proved to be shorter than in most isolates of *H. teres*, conidia seldom exceeding 100μ except in the Jerusalem oat leaf isolate. On the other hand many isolates of *H. teres* exceeded 100μ, and indeed 2 isolates produced conidia

on leaf lesions which attained the length of 350μ. Thickness of conidial wall is sometimes mentioned (Anderson 1954) as a character separating the two species; we found no perceivable difference between them in this respect in Israeli material. Catenulation is very common here with *H. teres* conidia, even on the leaf (Nishikado (1928) found it to be so to a degree), whereas is is rarely seen here in *H. avenae*.

Pyrenophora avenae when mature, tends to take an inverted pear-shape, whereas *P. teres* is hemispherical or even flattened on top. *P. teres* has never yielded mature ascospores here though many attempts were made to induce the fruiting bodies to reach maturity, using various conditions of temperature, light and nutritive media. *P. teres* is known to be refractory in regard to producing mature spores (Drechsler 1923); *P. avenae* here has been found to be quite fertile. Ascospores sown on PDA germinated and gave rise to colonies which produced in small numbers typical conidia of *H. avenae,* thus definitely proving the identity of the two forms in this case. Ascospores had the same septation and dimensions as Ito's (1931) and as Dennis's (1935) *P. avenae* and bore no resemblance to the *Pleospora avenae* Schaffnit et Rathschlag reported by Rathschlag (1930) in cultures of *H. avenae*.

H. avenae colonies on PDA gave no colour other than green, gray and white, whereas colonies of *H. teres* often secrete many coloured substances into the medium.

The results of our observations do not support Wehmeyer's grouping of many species of *Helminthosporium* on Gramineae under *Pleospora trichostoma* (Fr.) Ces. et De Not.* There are a number of reasons for the rejection of this combination :

1) The perfect stage of *H. avenae* possesses 5-septate spores as found here and elsewhere (Ito and Kurubayashi 1931, Dennis 1935, Dickson 1956), whereas those of *H. teres, H. tritici-repentis, H. bromi* and *H. tritici-vulgaris* are three-septate (Wehmeyer states that *P. trichostoma* is 3-septate). In other respects, the ascospores of *P. avenae* resemble his *trichostoma-mollis* type.

2) The shape of the perithecium among various species differs to a great extent, being on the one hand rather globose and sunken into the tissues in *P. bromi* and *P. tritici-repentis,* and provided with a beak set with setae, and on the other hand hemispherical, to inverted pear-shaped in *H. teres* and *H. avenae* respectively, strongly erumpent, and with the ostiole indistinct or missing. In the case of the latter two species, setae may be found all over the surface of the erumpent fruiting body. Wehmeyer mentions only setae grouped around the ostiolar process.

3) The shape and size of conidia of some of these species may resemble each other to a great extent, e.g. *H. teres, H. bromi, H. avenae,* and sometimes *H.*

* Dickson (1956) was of the mind that "a more systematic study of this group is necessary before combinations are justified".

gramineum, but it is easy to tell *H. tritici-vulgaris* apart from them, and these other species in turn have strong tendencies by which we may separate them by way of the imperfect stage. Thus, *H. gramineum* and *H. teres* are often catenulate, *H. avenae* seldom so; *H. gramineum* has conidiophores which arise in large groups whereas this is not so with the others. *H. teres* and *H. bromi* have greater maximum lengths than has *H. avenae.*

4) These species are pathogenic to different hosts, causing different diseases, or, if present on the same host, as are *H. teres* and *H.gramineum,* are easily separated by symptoms and disease cycle.

Helminthosporium cynodontis Marignoni (1909)

Found on: *Cynodon dactylon* (L.) Pers., on leaves; Rehovot, 14/I/56, 15/I/56, 16/IX/56; Nes Tsiyona, 2/I/57.

This fungus is common on Bermuda grass in the Coastal Plain during all seasons of the year. It causes a wilting and drying of the leaves, the affected parts having a dirty, slightly sooty appearance. No discrete blotches were found, but rather an effuse area.

Description of the fungus

Conidiophores: numerous on leaf, usually arising singly, but may be found in pairs and rarely in large caespitose groups. Sub-hyaline, fuligenous or tan; sinuous, with geniculations; basal cell abruptibulbous; bearing 1-5 conidia; 1-5 septate. 40-140μ × 3.8-6.3μ.

Conidia (Figure 4): fusiform, tapering to rounded ends, often slightly and evenly curved; contour smooth; peripheral walls thin; colour: sub-hyaline to fuligenous, sometimes light brown; hilum within contour of wall, narrow, shallow and inconspicuous, never dark brown; septa: up to 10-septate, but rarely that much; segments may be pod-like; germination: bipolar, most often with immediate forking of germ tube; spore measurements: 29.8-77μ × 9.8-14.7μ.

In culture: It grows rapidly on PDA even at cool temperatures, giving a colony of mousy-gray colour which in time turns olivaceous to almost black. Colonies are not dense and have a velvety appearance akin to mouse fur. Reverse is dark green with some light green and gray. Conidia are produced in very large numbers and closely resemble those taken from leaves, although maximum length was considerably shorter (52.5μ). Colonies may produce long sporophoric filaments near edge, which bear many conidia close to their apices.

Discussion

The many isolates examined by the writer seem to agree rather closely with the few extent descriptions, as do the symptoms of the disease itself (Drechsler 1923, Sprague 1950, Dickson 1956, Luttrell 1951). In a few respects our material deviates from Drechsler's: his fungus produced no spores on corn-meal agar, whereas ours is a prodigious producer of conidia on PDA; no attempt was made at present to grow it on corn-meal agar to check whether the medium was to blame for the lack of sporulation. Drechsler mentions that conidiophores arise singly or in pairs in his Florida material, but although the tendency was the same here, one instance of caespitose groups of conidiophores was seen as well. Marignoni's original description mentions "conidiophoris aggregatis", which would allow for such phe-

nomena. Drechsler mentions specifically that conidia are never brown, but in a few cases Israeli material gave light brown conidia.

Both Drechsler's and Luttrell's (1951) mention of the forking of germ tubes close to the conidia was borne out here. Drechsler makes mention of the disparity in width between conidiophores in his material and that in Marignoni's description, as the latter had 6-7μ, whereas Drechsler's was 4-6μ typically 5μ. The writer's material agrees closely with Drechsler's.

Helminthosporium dictyoides Drechsl. (1923)

Found on: *Festuca arundinacea* Schreb. in cultivation; Neve Ya'ar, 4/II/57, leg. Z. Gerechter.

This fungus causes a slightly netted blotch of fescue leaves. The plants were not severely infected, and stricken plants of this genus were not found by us elsewhere in the country. The form of lesion resembles that described by Drechsler (1923) — a blotch with some longitudinal and transverse streaks of darker brown colour.

Description of the fungus

Conidiophores: arising singly, in pairs and in threes from the leaf surface; colour of Javelle water to light olivaceous; geniculate, with dark scars at the points of attachment of conidia. 60-160μ × 6.3-7μ.

Conidia (Figure 5): obclavate, generally strongly and uniformly tapered from the basal end toward the apical end; straight; basal cell is widest and is usually greatly constricted at the septum and often displays the viper-head shape attributed to *H. tritici-repentis* Died.; peripheral wall thin; colour: yellowish-green (Javelle water), granular; hilum: within contour of wall, dark; septa: mainly 3-4-septate, with 6 septa occasionally seen, but even 9-septate conidia have been encountered; catenulation of conidia is common, the basal spores being larger and more septate and often possessing a long narrow apical cell. Often, extensions which function as conidiophores are produced from an intermediate cell of a basal conidium, and new conidia may be proliferated from its tip; germination: occurs readily in tap water and may be polar, or more usually bipolar, but occasionally from intermediate cells as well. The germ tube grows out straight from the apical cell, whereas from the basal cell it usually grows out at a right angle or acute angle. The basal cell often has a thin wall at right angles to the hilum. Germ tubes do not branch close to the conidia; spore measurements: 28 (66.5-96.3) 140μ × 13.4-18.2μ. Conidia are seldom longer than 105μ.

Cultural characters: on Sach's agar the fungus fruits abundantly; the conidia are obclavate, subhyaline, and have up to 7 septa.

Discussion

This is the first record of *H. dictyoides* found outside North America that the writer is aware of. The fungus found here more closely approaches in morphological characters that found by Graham (1955) on *Phleum pratense* which he designated as *H. dictyoides* Drechsl. var *phlei* Graham, than it does Drechsler's orig-

inal description and figures. Catenulation was not observed by Drechsler, but was common in Graham's material; nor was constriction at the basal septum seen by the former, whereas it was found by Graham in his material. Graham found neither of these features in isolates from *Festuca,* but here both these phenomena were common on such material. This therefore corroborates his assumption that the fungus on both hosts should belong to the same species.

Helminthosporium dictyoides Drechsl. (continued)

Found on: new host — *Brachypodium distachyum* (L.) Roem. et Schult.; Rishon LeZion, 14/III/57.

The fungus is associated with distinct, narrow (1-3mm) brown linear streaks, which reach the length of 1.5 cm; these streaks are found on both sides of leaves. The margin is distinct and there is no chlorosis of the leaf surrounding the streak.

Description of the fungus

Conidiophores: 112-140 (300)μ × 5.6-7μ, usually simple, but rarely they branch; basal cell somewhat bulbous; colour light brown; 3-5 septate.

Conidia: long, narrow, strongly obclavate, straight; basal or second cell widest; basal cell usually hemispheric or sometimes bluntly pointed in outline; apical cell is usually attenuated into a short or longer process; peripheral wall thin; sometimes constricted at basal cell, but considerably less than *H. dictyoides* on *Festuca* as found in Israel, both in number of spores showing this feature and in degree of pinching. Conidia are sometimes catenulate, but less than in the fungus found on *Festuca;* colour: pale greenish-yellow; septa: 3-8(10); hilum: within contour of wall, inconspicuous; germination: bipolar, with a germ tube extending straight out in apical cell and at an acute angle in proximal cell. Often 2 germ tubes arise from basal cell; spore measurements: 52.5-119μ × 11.2-16.1μ.

Discussion

The form of *Helminthosporium* found on *Brachypodium distachyum* in Israel seems to belong to *H. dictyoides,* for it bears a closer resemblance to Drechsler's diagnosis and figures than does the afore-described form found here on *Festuca arundinacea,* practicularly as regards shape of basal cell and the only slight constriction at basal septum. Although both Drechsler and Graham found a maximum of 7 septa present in their isolates, we have 10-septate conidia, albeit rare; it is seldom that more than 8-septate conidia were seen. The rare branching of conidiophores that was seen here was also figured by Drechsler (Plate 11, Eg). The usually attenuated apical cell that we observed is somewhat exceptional.

The form of lesion that appears on leaves of *Brachypodium distachyum,* does not resemble the net blotch on *Festuca* caused by *H. dictyoides,* but the lesions on *Phleum pratense* as described by Graham also show no similarity with net blotch.

As cross-inoculations with isolates from *Festuca* and *Brachypodium* were not yet carried out, the writer is refraining from giving the fungus on *Brachypodium* varietal status for the time being.*

Helminthosporium maydis Nishikado et Miyake (1926)

Perfect stage: *Cochliobolus heterostrophus* Drechsl.
Found on: *Zea mays*, white dent corn grown under irrigation for forage; Nes Tsiyona, 18/IX/56.

This fungus caused numerous small, elliptical or rectangular necrotic lesions on leaves, ca. 5-15 × 3 mm in size; lesions coalesce, forming larger blotches. The plants in the field remained stunted, and the leaves yellowed and dried up, causing a complete loss of the crop. Sowing of the corn had been staggered over a long period of time, and the later-sown corn contracted the disease to a greater degree than that sown earlier. Corn had been grown on that field two years previous to this crop. In February, 1957, corn stover from the stricken crop was collected (the field had been twice plowed in the interim) and some spores of *H. maydis* were seen together with a larger number of spores of *H. turcicum* Pass. which incidentally had not been isolated during the summer months from the living plants.**

Description of the fungus

Conidiophores: arise singly, in pairs or in threes from the leaves; short, light brown. 70 - 130μ × 4.2 - 5.2μ.

Conidia (Figure 6): fusiform, regularly curved, often lunate; tapers to narrowly rounded ends; peripheral wall thin; colour: greenish-yellow or light tan or light yellowish brown; hilum: within contour of wall; small, inconspicuous; septa: 0 - 10 9-septate being common; occasionally, almost full-sized spores may be continuous; germination: mostly bipolar; majority of germ tubes fork close to conidia; occassional germination from intermediate cells; spore measurements: 98 - 126μ × 14 - 15.8μ in fresh material; 42 - 84μ × 11.9 - 16.2μ in conidia from culture on PDA.

In culture: On PDA under various conditions of temperature, colonies were greenish-gray to dark gray and were fluffy at the edges, though not dense. Sporulation was prolific, particularly from sporophoric filaments. Catenulation (even 3 spores in a chain) although not very common, was by no means rare within the temperature range of 12 - 25° C.

---

* Since this paper was submitted, this fungus was found again on the same host near Nes Tsiyona, 24/II/58. All the above-mentioned characters hold true for this isolate except for overall measurements of conidia which were much larger in this case, being 98.0 - 217.0μ × 13.6 - 20.5μ. The far greater length is largely the result of the greatly extended tail, which may exceed the length of the body of the spore. The tail is 4.4 - 5.6μ wide along most of its length.

** In July 1957, the writer inoculated two corn plants in field rows with macerated mycelium and conidia of *H. maydis* grown on PDA. Within six days, most leaves of both plants showed typical symptoms of the disease, whereas all other corn plants in the row remained free of the disease.

Discussion

The completeness and degree to which the field was stricken with the disease would point to a relatively long sojourn of the organism in this field and perhaps in the country, but it is surprising to find that corn in general has in Israel remained almost free from any diseases of consequence except for *Ustilago zeae-maydis,* and that no disease of such catastrophic type has been recorded here (Reichert 1954). Only in the past few years, since the greatly intensified irrigation of summer crops here has begun, has there been the warm and moist microclimate that would allow fungi of this type to attack corn. It could be reasonably expected that such fungi, if and when introduced to the country, will find conditions much more favourable to its spread than a mere few years before.

Helminthosporium rostratum Drechsl. (1923)

Found on: *Sorghum vulgare* var. *sudanense* Piper; Rehovot, 15/VIII/56; Beit Dagon, 13/IX/56.
Found on: *Eragrostis megastachya* (Koel.) Lk.; Rehovot, 15/VIII/56.

This fungus is associated with large dark blotches (up to 0.5 cm long) on green leaves of Sudan grass in Israel; these lesions are straw-coloured with an inconspicuous brownish border.

Description of the fungus

Conidiophores: As they were mixed with those of 2 other species of *Helminthosporium* in the material on Sudan grass that was examined, the writer refrained from making any detailed notes. In culture on PDA they are very long, branched, and concolorous with the rest of the mycelium (sepia to reddish-brown); smooth, very closely septate; 5.6μ wide.

Conidia (Figures 7 and 8): tapers to both ends, generally widest from about 1/3 to halfway from basal end; conidia are relatively slender and the apical part is usually attenuated, with the apical cell abruptly rounded off. The basal cell is most frequently inflated somewhat, with a definite constriction at the septum; the basal cell, however, may be somewhat conical and without any pinching at the septa. Peripheral wall is thick except at tips of end cells; colour: deep brown to deep reddish-brown; basal and apical cells are always of a colour density different from that of other cells, i.e. less dense but not necessarily lighter in colour; hilum: protruding, conspicuous, very dark brown; septa: maximum of 15 septa seen on occasion. Basal and apical cell septa are invariably much thicker and more noticeable than the others; germination: polar or bipolar. Often 2 germ tubes grow out of either or both end cells, or fork close to the conidia; spore measurements: $84\text{-}168\mu \times 10.5\text{-}15.8\mu$, from leaf.

In culture: grows quickly on PDA at 28° C, giving a very dense velvety colony, at first deep green, turning sepia and becoming eventually blackish. The colony appears sooty; many conidia are produced on long conidiophores.

In all cases, changes occurred in the shape and size of the conidia, varying from small spores of less than 50μ in length with walls up to 3μ in thickness and complete deformation (even paisley-shaped) with either end of spore being very wide, to cultures bearing almost cylindrical conidia up to 75μ long, or else spores slightly wider at the apical extreme than elsewhere. Length and width vary greatly. However deformed the spores may be, the thick end septa and protruding hilum and the dark spore colour remains unchanged.

Discussion

This fungus does not seem to give cause for alarm as a serious threat to Sudan grass as does *H. turcicum*. In morphology, it corresponds closely to descriptions of it in literature (Drechsler 1923, Sprague 1950). In our observations, however, conidia have a width of only 10.5-15.8μ and in culture differ greatly from those in the wild, whereas Drechsler's conidia reached a width of 14-22μ and in culture were "altogether similar to those found in nature".

Helminthosporium sacchari (v. Breda de Haan) Butler

Found on: *Cymbopogon citratus* (DC.) Stapf; Rehovot, 24/II/57, 18/V/57.

This fungus is the cause of an "eye-spot" on lemon grass leaves which vary from 0.1 - 1.0 cm in length × 0.05 - 0.2 cm in width. These spots have straw-coloured centres which eventually turn gray, and are ringed by a narrow brown to red border. The spots may coalesce to form a wide necrotic stripe.

Lemon-grass is not yet a commercial crop in Israel; in this case the disease was found in a test plot. The fungus sporulates abundantly on lesions in the field in cool weather.

Description of the fungus

Conidiophores: arising singly or in pairs, occasionally in threes from leaf, amphigenously; golden brown; simple, bearing one or two conidia near tip; expanded at base; 3-4 septate. 84-280μ × 5.6-6.3μ.

Conidia: fusiform, usually evenly curved or at least bellied-out on one side, often even lunate, but occasionally straight; apical end broadly rounded, basal end rounded more sharply; colour: varies in isolates from deep yellowish-green to light golden-brown to medium or even dark olivaceous; peripheral wall: thin (moderately thick in one culture), not pinched at septa; hilum: within contour of wall; very small, dark, not conspicuous; septa: 8-9 are common, 10 maximum; segments often pod-like; sometimes septa are diagonal; germination: bipolar; germ tube generally unbranched for some distance from the spore; spore measurements: 42-98μ × 11.9-18.2μ.

In culture: On PDA, at room temperature, it produced a zonate, regularly outlined colony, deep greenish, densest in centre, with smooth low-aerial mycelium comprising mostly conidiophores. Conidia are produced prodigiously. Long sporophoric filaments are also present which are 3.5-4.2μ wide and carry many conidia near tip.

The contour of spores was often not regular; spores were wider in the one instance that they were cultured, compared to those samples taken directly ffom the leaf. Sometimes the end cells were more dilute in colour and less granular than the other cells. This was observed occasionally in material taken from the field in May; the basal cell septa were also at times slightly thicker than other septa.

Discussion

The writer feels justified in placing this fungus under *H. sacchari* (v. Breda de Haan) Butler, for although it does not reach the maximum length stated by some workers such as Mitra (1931), Sprague (1950) gives 24 - 93μ and Parris (1942,

1950) demonstrates the great variation displayed by isolates of this fungus, some of which tally closely in dimensions and colour with those examined here. The isolates observed here resemble *H. sacchari* most closely; furthermore, they cause symptoms on lemon-grass attributed to that species. Mitra (1931) mentions that end cells are often slightly paler than others, and this was found to be so in some of the writer's material. Butler's original description of the species has conidia which are much smaller even than those herein described. This aroused the comment of subsequent researchers, as nobody since seems to have found conidia of such small dimensions in *Helminthosporia* parasitic on lemon-grass, *Pennisetum* or sugar cane (the known hosts of *H. sacchari*).

Helminthosporium sorghicola LeFebvre et Sherwin (1948)

Found on: *Sorghum vulgare* var. *sudanense* Piper; Rehovot, 15/VIII/56, 19/I/56, 21/I/56.
Found on: *Sorghum halepense* (L.) Pers.; Nes Tsiyona, 17/IX/56.

This fungus was found on Sudan grass and Johnson grass on a number of occasions, together with *H. turcicum*, the cause of a much more serious leaf blight of these hosts. The fungus was associated with small round or elliptical purplish spots, often with straw-coloured centres which reach the size of about 1 cm. No zonate pattern, as reported by LeFebvre and Sherwin (1948) was observed, so that the common name given it in the United States, "target spot", does not apply to the material we have seen (LeFebvre and Sherwin mention however that with common Sudan grass, the type grown here, the target effect is much less evident or non-existent than in Tift Sudan). Straw standing in the field throughout the winter may bear tremendous numbers of conidiophores.

Description of the fungus

Conidiophores: usually arise singly or in pairs; geniculate, narrow, often greatly contorted near tip; small bulb at base; colour golden to dark brown. Short prolongations of conidia may serve as secondary conidiophores, but are uncommon. $52.5 - 133\mu \times 4.2 - 5.6\mu$.

Conidia (Figure 9): fusiform, usually slightly and uniformly curved, tapering to rounded ends; peripheral wall thin and not constricted at septa; colour: golden to olivaceous; hilum: within contour of wall, dark, wide, inconspicuous; septa: maximum of 10, often unequally spaced apart; segments often pod-like; germination: polar or bipolar, rarely intermediate. Germ-tube is single or may be branched close to conidium or at a distance from it; spore measurements: $38.5 - 80.5\mu \times 8.8 - 13.3\mu$.

In culture: On PDA grows quickly; colony produces gray mycelium which turns olivaceous; border of colony produces very many conidia, to the extent that it is almost black; beyond this area, whitish tufts are in evidence.

Discussion

The Israeli material seems to differ somewhat in a number of respects from that described by LeFebvre and Sherwin, particularly in maximum spore dimensions

and conidiophore width and in mean width of conidia. The American material showed conidia considerably larger than those in our material, theirs being 20-105μ × 8.5-20.6μ, with a mean of 14.1μ, this latter figure being greater than our maximum. The proliferation of secondary conidiophores by some spores, as mentioned and figured by LeFebvre and Sherwin, was found here as well, and is the only case of such phenomena found here on any of the *Eu-Helminthosporia* under consideration.

According to Luttrell's key, the dimensions of Israeli material would cause it to fall in the *H. cynodontis, H. leersiae* group (maximum diameter 14μ, maximum length less than 100μ, conidia ellipsoid to fusoid), rather than the *H. maydis, H. sorghicola, H. sacchari, H. nodulosum* group (maximum diameter more than 17μ, length not over 115μ). Luttrell (1951, 1954) makes it quite clear that these fungi are all very similar in most respects and can be separated only with difficulty on the basis of morphological characters. Parris in his work (1942, 1950) on the very variable species *H. sacchari,* showed the danger of depending too much on conidial dimensions, and Elliott (1948) and Nishikado (1928) demonstrated that nutrition plays an important part in determining the size of conidia in many species within *Eu-Helminthosporium.* It is not yet clear as to which characters deserve particular attention in working with the fungi named above in order to put them in their correct taxonomic niche.

Our material from Sudan grass resembles *H. cynodontis* in size and shape, and differs from it in colour; germ tubes of *H. cynodontis* usually fork at the conidium, whereas in the material herein investigated it may or may not do so; the hilum in the latter is darker than in the parasite on Bermuda grass, and colonies produced in culture differ. The Israeli fungus on Sudan grass closely matches *H. leersii* as described by Drechsler, except for colour and cultural aspects.

LeFebvre and Sherwin mention that *H. sorghicola* closely matches *H. maydis* but has less strongly curved conidia, is smaller and has fewer septa, all of which have been further verified in our studies.

On the basis of host, of type of lesion encountered, and of the general close similarity in morphological and cultural aspects aside from the exceptions just mentioned, there should be little doubt that we are dealing here with *H. sorghicola* LeFebvre and Sherwin.

Helminthosporium tritici-vulgaris Nishikado (1928)

Perfect stage: *Pyrenophora tritici-vulgaris* Dickson
Found on: *Triticum durum* Desf., on volunteer plants; Neot Mordekhai, 6/V/57.

This fungus causes a fusiform, yellowish-brown spot on leaves of wheat, with a darker centre usually present. Spots are numerous, and vary from 0.2 × 0.1 cm. to 0.8 × 0.2 - 0.4 cm. Leaves tend to dry up starting at tips of blades.

The disease has been found on only one occasion, in the Huleh Plain.

Description of the fungus

Conidiophores: arise singly or in pairs, sometimes in threes; light brown to olivaceous, lighter near apex; base somewhat bulbous; conidiophores only very slightly tapering or not at all; often the apical cell is expanded into a javelin-head shape; conidia borne singly at tip, in our material, though thin sporophoric filaments produced in a damp chamber may carry a number of spores; conidiophores 157.5 - 280μ × 6.3 - 8.4μ.

Conidia: (Figure 10) cylindrical, straight or irregularly straight, longer spores sometimes irregularly curved or bent and not equally wide throughout length. End cells may be rounded, or tapered to a rounded conical end. Peripheral wall very thin to moderately thick in larger spores, and is in all cases very thin at extreme tip of basal cell. There is little or no constriction at septa; colour: sub-hyaline to light yellow in smaller conidia, yellowish-green and granular in larger ones; hilum: never detected in this material; septa 1-7 (mostly 3-5); spore measurements: 80.5-168μ × 10.5-14.7μ; germination: bipolar and also from intermediate cells.

Discussion

The conidia and the tenuous connection between conidia and conidiophore seem to match those figured by Raabe (1937). The description given in Sprague's book closely approaches our material, except that we have found occasionally that conidiophores may arise in threes, whereas he states that not in groups of more than two; also, we found conidia borne only singly, whereas Sprague states that 1-3 conidia may be borne on conidiophores. It is quite possible that our material under other conditions will bear more than one conidium. Dickson (1956) states that conidiophores arise singly, in pairs or in threes.

Helminthosporium turcicum Passerini

Found on: *Sorghum vulgare* var. *sudanense* Piper; Rehovot, 15/VIII/56, 20/VIII/56, 19/I/57; Dorot, 16/IX/56; Deganim, 16/IX/56; Beit Dagon, 13/IX/56.
Found on: *Sorghum halepense* (L.) Pers.; Nes Tsiyona, 17/IX/56.
Found on: *Sorghum vulgare;* Rehovot, 8/X/56.
Found on: *Zea mays* (on plant debris); Nes Tsiyona, 3/II/57.

This fungus causes a very serious leaf blight of common Sudan grass in Israel in the Coastal Plain and in the South. Symptoms displayed on Johnson grass and grain sorghum closely resemble those on Sudan grass; on corn however, the fungus was isolated from leaf detritus found in the field in February and kept at 20°C in a damp chamber, so that symptoms on the living plant were not observed.

The effect of the disease on Sudan grass was nothing short of catastrophic; most of the leaves dried up and, at Rehovot, for instance, almost no seed was produced. The first signs were noticed when the disease was already well-advanced, and took the form described in literature (Sprague 1950), (Figure 11), — large elongated blighted areas with a bluish-gray tinge, later turning gray, with a brown to purplish border. Lesions are usually at first shield-shaped; later they may coalesce to form

stricken areas a number of centimetres long. The entire leaf may then dry up. Conidiophores are produced in large numbers on the lesions.

Description of the fungus

Conidiophores: arise singly or more frequently in pairs or in threes; dark brown (chestnut), smooth, 3-7 septate; 105-175μ × 6.3-7μ, slightly wider at base.

Conidia (Figure 12): fusiform, bulky, usually straight but sometimes irregularly bent somewhat, rounded broadly at apical end (although not truly pointed at basal end — the true shape being masked by the protruding colourless hilum); peripheral wall thin, and is either slightly pinched at septa or not at all constricted; conidia are held tenuously on conidiophores; colour: variable, subhyaline at first, later golden or greenish-yellow or olivaceous; granular or clear; septa: irregularly spaced, up to 8-septate, mostly 5-6, always horizontal; full-sized but immature hyaline conidia may be continuous; germination: bipolar; spore dimensions: 66.5-128μ × (13.3) 14-24.5μ.

In culture: On PDA it grows quickly at room temperature, ca. 20°C; colonies dark green to deep yellowish-green; dense mycelial mat; dentritic; conidia produced prolifically.

Discussion

Conidia from all sources closely resemble one another, and tally with descriptions of the species from other sources (Drechsler 1923, Sprague 1950). It is not a difficult species to identify immediately by inspection under the microscope, thanks to a few distinct and stable characters, e.g. the prominently protruding hilum, thin wall, bulkiness, unequally spaced septa, specific shape of conidia. A few isolates gave relatively narrow spores.

Although the disease is widespread in the South of Israel and in the Coastal Plain, it did not seem to have caught anyone's notice until now. The reason for this might be that Sudan grass has of late become popular in places as sown and irrigated pasture for the warm, dry months of the year, at the same time giving this fungus for the first time precisely the conditions it needs for producing epiphytotics (see also discussion on *H. maydis*). It is inevitable now, that some measures will have to be taken soon if the growing of this crop is not to be forfeited on account of this scourge.*

* Since this paper was submitted, a very serious outbreak of *H. turcicum* on irrigated corn occurred during late summer, 1957. A large field at Nir Am on the boundary of the northern Negev was severely attacked, not a leaf remaining free of the blotches. Other places where corn was stricken were Mivhor in the Shefela, Na'an and Midreshet Ruppin in the Coastal Plain and Ramat Hashofet in the hills of Ephraim. There is little doubt that the new practice of growing corn a number of years in a row in the same field or with only a short green-manure crop in between corn crops, as well as the practice of overhead irrigation contributed greatly in preparing the stage for this epiphytotic.

Records of this fungus in Israel on corn date back to 1938 according to Rayss (1943), and we have examined dried corn leaves from 1942 at the herbarium of the Agricultural Experiment Station at Rehovot, and found *H. turcicum* to be present. Only the particular growing conditions of the past few years have allowed this disease to rise in stature and to become a threat.

A KEY TO SPECIES OF HELMINTHOSPORIUM ON GRAMINEAE IN ISRAEL

A. Conidia fusiform, generally germinating by polar germ tubes. Perfect stage, when known, *Cochliobolus*, or in a few instances, *Metasphaeria*.

I. Hilum protruding.

a. conidia thick-walled, dark-olive to reddish-brown; often with a rostrate apex. *H. rostratum* Drechsl.

b. conidia thin-walled, sub-hyaline to olivaceous, never rostrate. *H. turcicum* Passerini

II. Hilum contained within contour of peripheral wall of conidia.

a. conidia thick-walled, bulky, straight or curved, generally olivaceous to dark olivaceous. *H. sativum* P. K. et B.

b. conidia thin-walled.

1. maximum length of conidia below 80μ.

a) germ-tubes branch close to conidium; causes sootiness and drying-out of leaves of *Cynodon dactylon*. *H. cynodontis* Marig.

b) germ-tubes generally branch at distance from conidia; conidia occasionally catenulate; leaf-spot of *Sorghum vulgare* var. *sudanense*. *H. sorghicola* LeFebvre et Sherwin

2. maximum length of conidia 100μ or more.

a) maximum length of conidia 100μ; end cells sometimes more dilute than others. eye spot of *Cymbopogon citratus*. *H. sacchari* (v. Breda de Haan) Buttler

b) maximum length reaches 130μ; a leaf-spot on *Zea mays;* conidia occasionally catenulate in culture. Perfect stage is *Cochliobolus heterostrophus* Drechsl. *H. maydis* Nishikado

B. Conidia cylindrical or obclavate, generally germinating at polar and intermediate cells. Perfect stage, when known, *Pyrenophora*. *Cylindro-Helminthosporium* Nishikado

I. Conidia only obclavate, basal cell often enlarged; causes net blotch of *Festuca* and linear spot of *Brachypodium*. *H. dictyoides* Drechsl.

II. Conidia cylindrical to sub-cylindrical.

a. hilum missing or very inconspicuous; basal cell may taper; causes yellow spot of wheat. *H. tritici-vulgaris* Nishikado

b. hilum rather conspicuous.

1. conidiophores often arise in caespitose groups on long necrotic stripes on barley; cultures normally yield no spores. *H. gramineum* Rabh.

2. conidiophores seldom arise in large caespitose groups and in such large numbers; conidiophores often expanded considerably at base.

a) Fruiting bodies (*Pyrenophora avenae*) often inverted pear-shaped; ascospores 5-septate transversely; colonies green or gray; conidia seldom catenulate; causes various spots and streaks on *Avena* spp. *H. avenae* Eidam

b) Fruiting bodies (*Pyrenophora teres*) hemispherical or flattened on top; mature ascospores not produced in Israel, asci very rarely produced. Conidia occasionally may reach a length of 350μ; catenulation common; causes net blotch of barley. *H. teres* Sacc.

ACKNOWLEDGEMENTS

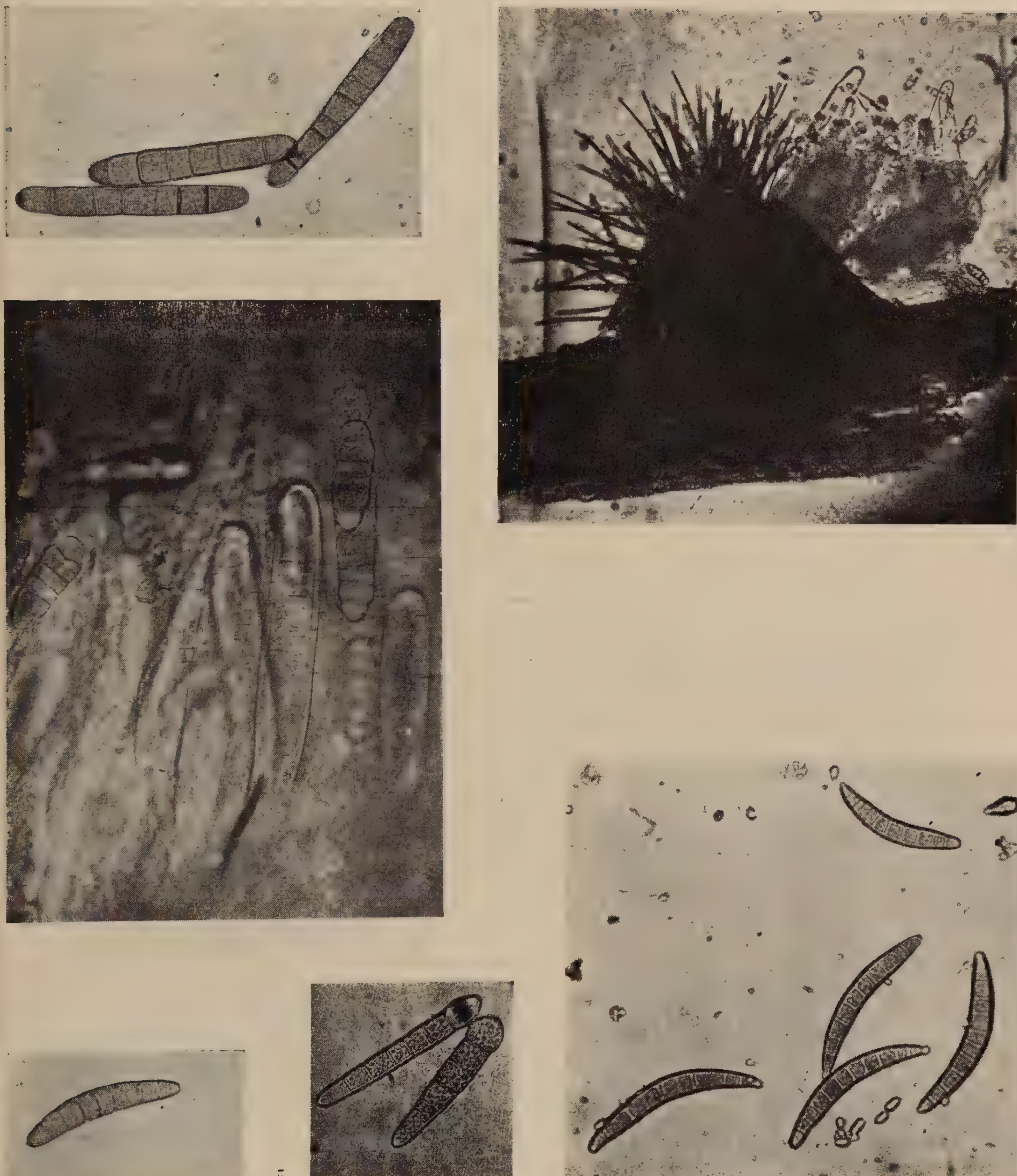
The writer wishes here to express his deep appreciation to Dr. I. Wahl of the Department of Plant Pathology of the Faculty of Agriculture of the Hebrew University, for his encouragement in the pursuance of this work.

Thanks are also rendered to Dr. N. Feinbrun and Dr. J. Lorch of the Department of Botany of the Hebrew University, for the determination of *Brachypodium distachyum*.

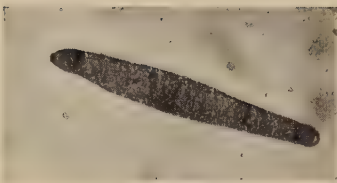
REFERENCES

1. Anderson, H., 1954, Species of *Helminthosporium* on cereals and grasses in Denmark, *Friesia, 5,* 80-89.
2. Dennis, R.W.G., 1935, Notes on the occurrence of *Pyrenophora avenae* Ito, in Scotland, *Brit. myc. Soc. Trans., 19,* 288-290.
3. Dickson, J. G., 1956, *Diseases of Field Crops,* 2nd ed., McGraw-Hill, New York.
4. Drechsler, C., 1923, Some graminicolous species of *Helminthosporium*: I, *J. agric. Res., 24,* 641-740, illustr.
5. Elliot, E. S., 1948, Effects of sugar concentration on the size of the conidia produced by *Helminthosporium victoriae, Phytopathol., 39,* 953-958.
6. Graham, J. H., 1955, *Helminthosporium* leaf streak of timothy, *Phytopathol., 45,* 227-229.
7. Ito, S. and Kurubayashi, K., 1931, The ascigerous forms of some graminicolous species of *Helminthosporium* in Japan, *J. Facul. agric. Hokkaido imp. Univ. Sapporo, 29,* 85-125 (English).
8. LeFebvre, C. L. and Sherwin, H., 1948, An undescribed species of *Helminthosporium* on Sudan grass and sorghum, *Mycologia, 40,* 708-716.
9. Luttrell, E. S., 1951, A key to species of *Helminthosporium* reported on grasses in the United States, U.S.D.A. Pl. Dis. Rep. Suppl. *201,* 59-67.
10. Luttrell, E. S., 1954, Approaches to the classification of *Helminthosporium* species, U.S.D.A. Pl. Dis. Rep. Suppl. *228,* 111-113.
11. Luttrell, E. S., 1957, *Letosphaeria* (*Metasphaeria*) perfect stages for *Helminthosporium turcicum* and *H. rostratum, Phytopathol., 47,* 313.
12. Mitra, M., 1931, A comparative study of species and strains of *Helminthosporium* on certain Indian cultivated crops, *Brit. myc. Soc. Trans., 15,* 254-293.
13. Nishikado, Y., 1928, Studies on the *Helminthosporium* diseases of *Gramineae* in Japan, Ohara Inst. Agric. Res., Spec. Rpt. 4, 394 pp. (English summary in Ohara Inst. f. Landw. Forsch. Ber. *4,* 111-126, 1929).
14. Parris, G. K., 1942, Eyespot of Napier grass in Hawaii, caused by *Helminthosporium sacchari, Phytopathol., 32,* 46-63.
15. Parris, G. K., 1950, The *Helminthosporia* that attack sugar cane, *Phytopathol., 40,* 90-103.
16. Putterill, K. M., 1954, Some graminicolous species of *Helminthosporium* and *Curvularia* occurring in South Africa, *Bothalia, 6,* 347-348.
17. Raabe, A., 1937, *Helminthosporium tritici-vulgaris* Nis., einige Erreger Blatt-Krankheit des Weizens, *Phytopathol. Ztschr., 10,* 111-112.
18. Rathschlag, H., 1930, Studien über *Helminthosporium avenae, Phytopathol. Ztschr., 2,* 469-492.
19. Rayss, T., 1943, Contribution à l'Étude des Deuteromycètes de Palestine, *Palest. J. Bot. Jerusalem, 3,* 22-51.

20. Reichert, I., 1954, The occurrence of plant diseases in arid climates and their agricultural significance, Biology of Deserts, *Proceedings of the symposium on the Biology of Hot and Cold Deserts,* Inst. of Biol., London pp. 68-75.
21. Sprague, R., 1950, *Diseases of Cereals and Grasses in North America,* Ronald Press, New York.
22. Wehmeyer, L. E., 1949, Studies in the genus *Pleospora.* I, *Mycologia, 41,* 565-593.
23. Wollenweber, H.W., 1932, *Hyphomyceten, Dematiaceae, Helminthosporiae,* in *Sorauer's Handbuch der Pflanzenkrankheiten, 3,* 577-830.



1. *Helminthosporium avenae*: conidia. 2. *Pyrenophora avenae* (=*H. avenae*) on straw of *Avena sterilis*: fruiting body showing setal and expressed asci and ascospores. 3. *P. avenae*: asci and ascospores. 4. *H. cynodontis*: conidium. 5. *H. dictyoides*: conidia. 6. *H. maydis*: conidia — commencement of germination.


7


9


8


10


11


12

7-8. *Helminthosporium rostratum*: conidia. 9. *H. sorghicola*: conidia. 10. *H. tritici-vulgaris*: conidium. 11. *Sorghum vulgare* var. *sudanense* — symptoms caused by *H. turcicum* on leaf (ca. × 3). 12. *H. turcicum*: conidium.

ANALYSIS OF WINDBREAK EFFECTS *

J. Lorch

Department of Botany, The Hebrew University of Jerusalem

ABSTRACT

The effect of windbreaks is generally evaluated by measuring their influence on wind speed. The per cent of decrease in wind pressure and energy due to a decrease of, say, 10 per cent in wind speed is independent of the initial, unbroken wind speed. On the other hand, a similar per cent of decrease in wind speed produces widely different effects on transpiration, photosynthesis and other processes — here conveniently discussed under the heading "physiological" — depending on whether the free wind speed is high or low. The breaking of strong winds, in particular, has a comparatively small effect on the "physiological" functions affected by wind, while at the same time pressure and energy (second and third degree functions of wind speed respectively) are considerably reduced. Analysing two cases of outstanding windbreak effectiveness — bananas in the Jordan Valley, Israel, and wheat in Canada—it is found that the variation in yield follows the pattern of wind damage to leaves, and of soil moisture produced from snow drifts, respectively. Both these patterns, though reflecting transient wind conditions, persist and are effective even in calm air; both are related to physical action of wind, to wind pressure and energy, which respond markedly to any decrease in wind speed. Therefore, the benefit derived from protecting crops which are not physically damaged by wind in fields not subject to snow drift may be assumed to reach, at best, only a small fraction of the benefit observed in the above instances. All available evidence shows that the so-called effective range of a windbreak depends on the purpose for which it is grown not less than on its height and density.

INTRODUCTION

Although in various countries windbreaks are considered an economically sound agricultural investment, estimates of the effective range of a windbreak are strikingly different. It is the purpose of this paper to attempt an explanation of the widely divergent views of workers on this subject, by discussing some fundamental aspects of windbreak effects. The discussion is based on observations made by the author (Lorch 1951) and by Smueli (1953) in the banana plantations of the Jordan Valley, Israel, just south of Lake Kinnereth, and on relevant published data.

* Based on a thesis for degree of M. Sc. Agr. at the Faculty of Agriculture of the Hebrew University, Rehovot, Israel, submitted in 1951.

BANANAS : YIELD IN RELATION TO PROTECTION FROM WIND

The wind which prevails in the Jordan Valley from May to September, the season of strongest growth of bananas, has long been known to justify the provision of artificial or live windbreaks, in spite of the considerable cost and loss of arable land involved. Generally, the windbreaks are 5-6 m in height and about 25 m apart. Each windbreak protects seven to eight rows of bananas, 3 m apart. The effect of the windbreak was evaluated by means of anemometers, as well as by observing the condition of the plants.

Leaves of bananas reach a size of 160 by 40 cm. Like those of many other monocotyledons, the have few and poorly developed cross-veins and are thus easily torn by wind.

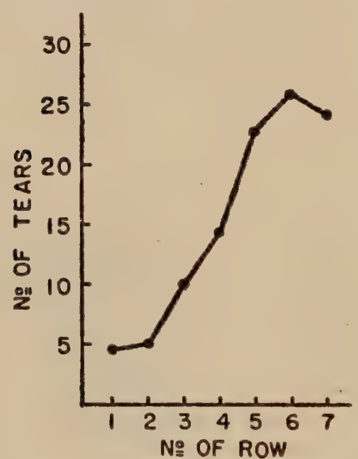


Figure 1

1st year plantation, June, 1953: Mean number of tears in one-week old leaves. Distance between consecutive rows — 3 m. Each point represents the average for 40 plants.

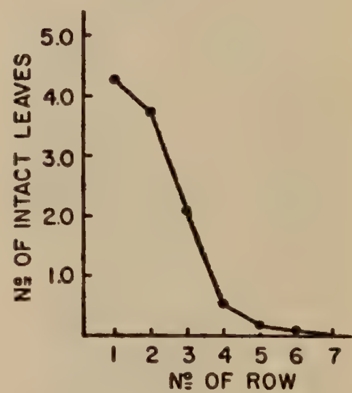


Figure 2

Same as Figure 1: Mean number of intact leaves per leaves with no more than 2 tears per plant. Each point represents the average for 45 plants.

TABLE I

Average yield of bananas by row at Degania
(a) mean weight of bunch in kg, (b) the same in per cent of average for all rows

No. of row		1	2	3	4	5	6	Average
Second year protected by	(a)	16.2	18.1	18.4	18.1	16.4	14.9	17.0
Sesbania	(b)	95.3	106.5	108.2	106.5	96.5	87.6	100
First year protected by	(a)	11.3	11.5	10.9	10.7	10.0	9.3	10.6
reed fences	(b)	106.6	108.0	102.4	100.8	94.5	87.8	100

It is evident (Figures 1-4 and Table I) that yield, number of tears per leaf, the reciprocal number of intact leaves per plant and relative wind velocity, all show common trends. What is the causal connection between these trends?

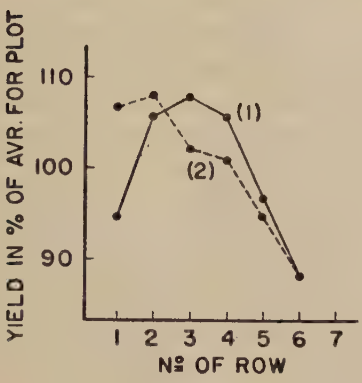


Figure 3

Average weight of bunch (a) in kg (b) in per cent of average for all rows. Averages of 25-40 bunches. (1) Second year plantation, protected by a live windbreak of *Sesbania aegyptiaca* (2) First year plantation protected by an artifical windbreak of reed fences. Note the severe competition of the *Sesbania* with the best protected row, which yields much less than the corresponding row protected by the reed fence.

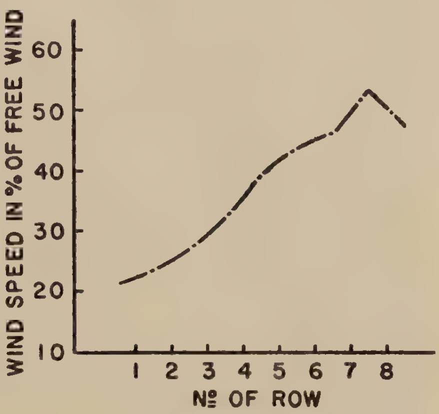


Figure 4

Typical wind profile at 2 m in lee of windbreak 5 m in height in a first year plantation. Wind speed shown as per cent of free wind speed in an open field 500 m to the north. Distance between rows — 3 m.

Shmueli (1953), in an intensive study of the responses and moisture requirements of banana plants in the Jordan Valley, states "Among the factors which affect transpiration, wind velocity appears to exert the most prominent effect". Unfortunately, he does not compare rates of transpiration at varying distances from windbreaks, yet he assumes "that the higher yields obtainable from rows of banana adjacent to windbreaks are the result of a more favourable water balance of the plants concerned".

Though this appears to be the prevalent explanation of the beneficial effect of windbreaks on crops, the following analysis of the various effects of wind on plants raises grave doubts.

THE EFFECT OF WIND ON TRANSPIRATION AND OTHER PROCESSES IN PLANTS

Seybold (1929) asserts that wind has no effect on the rate of stomatal transpiration of plants. His opinion is apparently corroborated by data obtained by Briggs and Shantz (1916) who estimated that only 2-6 per cent of the total water consumption of their plants were due to variation in wind velocity. Harder (1930), no

doubt misled by Seybold (1929), believes that extensive areas in the Sahara with sparse perennial vegetation would be quite bare throughout summer were it not for the wind which blows almost without interruption, preventing undue overheating of plants exposed to intensive sunlight, so that there is no increase in their water requirements. Five years later, Harder (1935) admitted the untenability of this view in the light of data collected by one of his students, as well as by Firbas (1931) and Stalfelt (1932). In this second article on the subject, Harder admits that the transpiration of each of the 12 species investigated by his student increased following an increase in wind velocity. Concluding, he makes the reasonable claim that wind may benefit desert plants under extreme conditions.

The attempt made by Briggs and Shantz (1916) to correlate *mean* daily wind velocity with water consumption yielded unlikely results; first, because several environmental factors were changing simultaneously; secondly, because any correlation between *mean* daily wind speeds and *mean* daily values of transpiration is possible only on the assumption of a linear relation between wind speed at any given moment and transpiration. Yet such an assumption is contrary to the facts. On the other hand, the short-term variability of wind makes it practically impossible to obtain data of wind speed truly comparable with the momentary rates of transpiration determined by the quick weighing method (Huber 1930), even assuming Huber's method to be completely reliable.

The obvious escape from these handicaps is the use of fans to ventilate plants in a controlled environment. Thus, Gäumann and Jaag (1939 a, b), who so far carried out the most extensive experiments on the relation of wind to transpiration, used a specially constructed wind tunnel in which temperature and relative humidity were almost constant. To reduce turbulence, the wind tunnel was provided with straightening vanes which kept wind velocity within ± 2 per cent of the experimental value. Soil moisture is briefly reported as "optimal". Neither the criterion by which moisture was judged to be optimal, nor the exact amount of moisture are indicated. Martin and Clements (1935), working with sunflowers, used ordinary fans which produced a rather more variable wind. Soil moisture is said to have been maintained at 65 per cent of saturation. There is no indication of how this was done.

It appears that the methods of both these teams, though not without much promise as a preliminary approach, fail to determine the physiological effects of wind under natural conditions. Firstly, because the steady wind involves a continuous stress on the plant organs and precludes recovery effects associated with normal, more or less gusty wind. Such recovery, however, must be expected to be of general occurrence with unsteady winds, at least under conditions of satisfactory water supply. The second factor which prevents the direct application of the results obtained by Gäumann and Jaag and by Martin and Clements to irrigated crops, such as the banana, is the excessive simplification of the soil moisture aspect. For, as Shmueli (1953) has shown for bananas, plots 2, 6, 8 or 12 days after irrigation

show very different rates of transpiration. Similar results have been obtained with other crops.

A complete analysis of the physiological effects of wind would of course have to include data on respiration and photosynthesis. In a study of CO_2 uptake, Deneke (1931) found the rate of uptake to increase with wind speed rising from calm. The increase in rate of uptake became proportionately smaller when wind speed approached 6 km/hr. There was no further increase above that speed *. At times which are critical for wind protection this factor may, therefore, be neglected.

Also, as Gäumann and Jaag (1939a) seem to have been the first to assume, shaking of leaves by wind may involve interference with the normal functioning of the cells. This was confirmed by Kahl (1951), working with a shaking apparatus. She found shaking to have a depressing effect on photosynthesis.

The results obtained by Gäumann and Jaag (1939a), Martin and Clements (1935), Nakayama and Kadota (1949), Stalfelt (1932) and others, permit some statements on the general dependence of transpiration on the velocity of wind and on the relation between wind velocity and physiological processes in plants in general. Their data suffice to show that if a linear relation between rate of transpiration and wind velocity does exist at all, it is certainly confined to the range of lowest wind velocities. With wind speed rising beyond this range, the rate of transpiration asymptotically approaches a limit which is determined by factors other than wind speed. This conclusion is of crucial importance in any consideration of windbreak influences on plants. It implies that while the effect of a windbreak on wind—expressed in per cent of the free wind—is independent of the velocity, at least within a wide range (Lorch 1951 and others), the protective influence, in terms of the physiological effects, decreases sharply with increasing wind speed. Indeed, with any but the lowest wind speeds, the protective effect on the physiological processes of the plant is much less pronounced than the corresponding protective effect on wind velocity.

THE PHYSICAL EFFECTS OF WIND

These effects have been variously discussed in connection with soil drifting (Zingg and Chepil 1950, Stoeckeler 1938), snow drifting (Onodera 1954, Staple and Lehane 1955), fruit drop (Reed and Bartholomew 1930, Webber and Batchelor 1948), unequal distribution of water by sprinklers (Korven 1952), requirement of feed (Stoeckeler and Williams 1949) or fuel (Bates 1945, Woodruff 1954).

Though wind is usually referred to in terms of its velocity, discussion of windbreaks is mainly concerned with either the pressure exerted or the energy involved.

* Wilson and Wadsworth (1958) obtained a somewhat different relation between CO_2 uptake and wind speed, yet they, too, confined their research to wind speeds up to 6 km/hr.

Wind pressure may be calculated by the following equation in which pressure changes as the square of the velocity :

$$p = 0.06\, \varrho\, v^2 \tag{1}$$

where ϱ is the density of the air in kg/m³, p — wind pressure in kg/m², v — wind velocity. The energy of wind, per unit time, may be calculated by equation (2) in which energy changes as the cube of the velocity :

$$E = k \cdot A \cdot v^3 \tag{2}$$

where E is the output in horse power, k — a constant determined by the physical properties of air and by the units used, v — wind velocity. A somewhat similar equation, proposed by Bagnold (1941), shows the relation between the amount of sand blown by wind and the corresponding wind velocity:

$$g = 5.2 \times 10^4 (v - v_t)^3 \tag{3}$$

where g is the rate of sand movement in ton for each m at a right angle to the direction of the wind, v_t — the threshold value of wind velocity at which sand blowing starts, in m/sec. v and v_t are measured 1 m above ground; the mean diameter of the sand grains was 0.25 mm.

By contrast with wind pressure and energy, the dry cooling power of the air (Hann 1932), and evaporation from open water and from wet soil (Penman 1948) are first degree functions of wind speed *. Evaporation from a Piche tube was recently found to be similarly related to wind speed (Wächterhäuser 1954).

YIELD VS. ENVIRONMENT

In the light of the above data it appears that wherever yield of any crop changes rather abruptly with increasing distance from a windbreak, this variation in yield should not be ascribed to the influence of wind on transpiration. For both the rate of change of the physiological effects of wind in lee of a windbreak, and the distance from the windbreak at which these effects change most markedly, depend on the wind speed prevailing at any moment. In this, the possible microclimatic effects of windbreaks (Gloyne 1954, Bates 1944, Arzt 1950) may be of some influence.

Not so the physical effects of wind. Putnam (1948), who approaches the problem from an "anemophilous" angle, has emphasized that a 20 per cent increase in wind velocity involves an increase of 73 per cent in the kinetic energy of the

* According to Huber (1930), evaporation from a system of perforated membranes, such as he considers to be provided by the stomata of plants, responds to wind even less than evaporation from open water.

wind. In terms of the "anemophobous" windbreak approach, this is equivalent to saying that any 20 per cent decrease in velocity involves a 40 per cent decrease in wind power, the rate of change being independent of the distance behind the fence and the wind speed. Unfortunately, reliable data on yield vs. wind speed are rather few and generalized (Kreutz 1937), yet the impression is one of a very gradual change of yield with distance from windbreak. This is not so in the banana plantations of the Jordan Valley and in the case recently reported by Staple and Lehane (1955). Here yield of wheat varied markedly within a short distance, although much less than with bananas. Correlation with wind speed was good. Further data, however, indicated that the decisive factor was an increase in available soil moisture and that "the areas of increased soil moisture use corresponded roughly with those occupied by snow drift in winter". Snow drift, however, is obviously determined by changes in the physical effects of wind.

As shown above, in the banana plantations of the Jordan Valley a change in wind speed from 60 to 30 per cent of the free wind speed 2 m above ground involved an increase from 88 to 108 per cent of the mean yield of the plantation. The above discussion of the widely different response of the various physical and physiological effects of wind to change in wind speed suggests that the exceptionally good effect of windbreaks on bananas grown in the Jordan Valley should be mainly ascribed to the prevention of leaf-tearing by windbreaks. It appears certain that the interference with normal photosynthetic activity and translocation—owing to the mechanical damage to leaves—rather than the direct effect on transpiration, are the major causes of the decrease in yield of bananas with decreasing protection from wind.

There is yet another fundamental similarity between the varying yields of bananas and wheat with increasing distance from a windbreak, discussed above. In both these cases, the effect of the windbreak, though originally confined to windy periods, becomes, as it were, impressed on the fields and henceforth affects the development and the productivity of the plants, wind or no wind. For the snow, once deposited and melted, produces in the field a pattern of moisture distribution which reflects the initial windiness pattern during the snowdrifts, even though this pattern no longer repeats itself. The same applies to the damaged leaves of the bananas which reflect the pattern of windiness in the hours of strongest prevailing winds.* But the damage, once done, is there to stay. And it is because of this that the pattern of windiness is plastically reflected in the weight of the bunches.

Just as in the Canadian wheat fields the wind-made pattern of snow-produced moisture becomes blurred with progressing evapotranspiration, so a period of

* A detailed analysis of hourly winds during the summer months in the Jordan Valley will be published by the Meteorological Service of Israel.

weak winds, which do not exceed the threshold speed necessary to tear the leaves of bananas, would permit the young leaves of bananas—unfurled during summer at the rate of one leaf per week—to function normally, thus blurring the pattern of windiness between the windbreaks. Unfortunately, such calm periods are quite unlikely in the Jordan Valley during the decisive summer months.

It is indeed strange that while so much discussion has been going on about the effective range of windbreaks, none of the scores of relevant articles seen by the author goes beyond stating the effective ranges in terms of a first degree or second degree function of the height of the windbreaks and their density.

Yet one cannot overemphasize the fact that the effect of a windbreak on the *velocity* of the wind, though certainly most easily measured**, does not in itself provide an adequate measure of other windbreak effects. For, while changes in the physical effects of wind are generally independent of the absolute velocities involved, the physiological effects, such as influence on transpiration, depend not only on the relative change of wind speed, but also on the absolute velocity at which such change occurs.

Owing to this fundamental difference between the physical and physiological aspects of wind action, the disagreements between various authors on the effective range of windbreaks are due to misunderstanding. The "effective range" of a windbreak depends on the purpose for which it is grown not less than on its height or density.

Note: D. Siev of Degania has since obtained the following results by artificially lacerating the leaves of bananas which were growing close to a windbreak, in the best protected rows of bananas, in a plot of the Jordan Valley Experimental Committee:

	Leaves normal	*Leaves lacerated*
(a) No. of "hands" per bunch	9.0	8.4
(b) No. of bananas per hand	15.1	13.8
(c) Weight of bunch (kg)	16.3	13.6

Statistically, the differences in both (a) and (c) were found to be highly significant; those in (b) almost so. Mean weight of bunch for the whole plot was 12.1 kg.

In an adjacent plot, mean weights of bunch varied from 11.7—17.0 kg in the least protected and best protected row respectively. Comparing this with the above data, Siev believes that more than half of the beneficial effect of the windbreak is due to the prevention of mechanical damage to the leaves.

REFERENCES

1. Arzt, T., 1950, Mikroklimatische Untersuchungen über Windschutz, *Phyton, 2,* 157-181.
2. Bagnold, R.A., 1941, *The Physics of Blown Sand and Desert Dunes,* London.

** Most easily, though not cheaply — see measurement by Piche evaporimeters (Lorch 1951).

3. BATES, C. G., 1944, revised, The windbreak as a farm asset, *USDA, Farmer's Bull.* 1405.
4. BATES, C. G., 1945, Shelterbelt influences. II — The value of shelterbelts in house heating, *J. For., 43,* 176-197.
5. BRIGGS, L. J. and SHANTZ, H. L., 1916, Hourly transpiration rates on clear days as determined by cyclic environmental factors, *J. agric. Res., 5,* 583-651.
6. DENEKE, H., 1931, Über den Einfluss bewegter Luft auf die Kohlensäureassimilation, *Jahrb. wiss. Bot., 74,* 1-32.
7. FIRBAS, F., 1931, Die Wirkung des Windes auf die Transpiration, *Ber. dtsch. bot. Ges., 49,* 443-452.
8. GAEUMANN, E. und JAAG, O., 1939a, Der Einfluss des Windes auf die pflanzliche Transpiration. I, *Ber. schweiz. bot. Ges., 49,* 179-238.
9. GAEUMANN, E. und JAAG, O., 1939b, Der Einfluss des Windes auf die pflanzliche Transpiration. II, *Ber. schweiz. bot. Ges., 49,* 555-626.
10. GLOYNE, R. W., 1954, Some effects of shelterbelts upon local micro-climate, *Forestry, 27,* 85-95.
11. HANN, J., 1932, *Handbuch der Klimatologie,* Stuttgart.
12. HARDER, R., 1930, Beobachtungen über die Temperatur der Assimilationsorgane, *Z. Bot., 23,* 703-743.
13. HARDER, R., 1935, Über die oekologische Bedeutung des Windes für die Wüstenvegetation, *Nachr. Ges. Wiss. Göttingen, Biologie, N. F., 1,* 182-188.
14. HUBER, B., 1930, Untersuchungen über die Gesetze der Porenverdunstung, *Z. Bot., 23,* 839-891.
15. KAHL, Helene, 1951, Über den Einfluss von Schüttelbewegungen auf Struktur und Funktion des pflanzlichen Plasmas, *Planta, 39,* 346-376.
16. KORVEN, H. C., 1952, The effect of wind on the uniformity of water distribution by some sprinklers, *Sci. Agric., 32,* 226-240.
17. KREUTZ, W., 1937, Agrarmeteorologische Studien über Bestandsklima, Windschutz und Transpirationsverhältnisse im Gewächshaus, Reichsamt für Wetterdienst, Wiss. Abt. *2,* 7.
18. LORCH, J., 1951, Observations on windbreaks in the banana plantations of the Jordan Valley, M. Sc. Agr. Thesis, Faculty of Agriculture, The Hebrew University, Rehovot (Hebrew).
19. MARTIN, E. V. and CLEMENTS, F. E., 1935, Studies of the effect of artificial wind on growth and transpiration in *Helianthus annuus, Plant. Physiol., 10,* 613-636.
20. NAKAYAMA, M. and KADOTA, M., 1949, The influence of the wind on the transpiration of some trees. II, *Bull. Physiogr., Sci, Res. Inst., Tokyo University,* pp. 10-17.
21. ONODERA, S., 1954, Influences of windbreaks or forests on snow deposition, *J. Jap. For. Soc., 36,* 300-307.
22. PENMAN, H. L., 1948, Natural evaporation from open water, bare soil and grass, *Proc. roy. Soc., A, 193,* 120-145.
23. PUTNAM, P. C., 1948, *Power from the Wind,* New York and London.
24. REED, H. S. and BARTHOLOMEW, E. T., 1930, The effects of desiccating winds on citrus trees, *U. of Cal., Coll. of Agr., Bull.* 484.
25. SEYBOLD, A., 1929, Untersuchungen über die Transpirationswiderstände und über die Temperatur aegyptisch-arabischer Wüstenpflanzen, *Planta, 9,* 270-350.
26. SHMUELI, E., 1953, Irrigation studies in the Jordan Valley. I, *Bull. Res. Counc. Israel, 3,* 228-247.
27. SIEV, D., 1952, A comparison of two types of windbreaks (in Hebrew), *Banana Studies,* pp. 128-129, Tel-Aviv.
28. STALFELT, M. G., 1932, Der Einfluss des Windes auf die kutikuläre und stomatäre Transpiration, *Svensk bot. Tidskr., 26,* 45-69.
29. STAPLE, W. J. and LEHANE, J. J., 1955, The influence of field shelterbelts on wind velocity, evaporation, soil moisture and crop yield, *Can. J. agric. Sc., 35,* 440-453.
30. STOECKELER, J.H., 1938, Shelterbelt planting reduces wind erosion damage in W. Oklahoma, *J. Amer. Soc. Agron.,* 923-931.

31. Stoeckeler, J. and Williams, R. A., 1949, Windbreaks and shelterbelt trees, *USDA Yearbook* 1949, 191-200.
31a. Wachterhauser, H., 1954, Die Verdunstungsmengen des Piche Evaporimeters in ihrer korrelativen Abhängigkeit von Sättigungsdefizit und Wind, *Angew. Bot., 28,* 192-201.
32. Webber, H. J. and Batchelor, L. D., editors, 1948, *The Citrus Industry.* II, Univ. of California Press.
33. Wilson, A. J. and Wadsworth, R. M., 1958, The effect of wind speed on assimilation rate, *Ann. Bot., Lond., 22,* 285-290.
34. Woodruff, N. P., 1954, Shelterbelt and surface barrier effects on wind velocities, evaporation, house heating and snowdrifting, *Kansas agric. Exp. St.,, Tech. Bull.* 77.
35. Zingg, A. W. and Chepil, W. S., 1950, Aerodynamics of wind erosion, *Agric. Engng., 31,* 279-282.

PHYSIOLOGICAL STUDIES ON THE DEVELOPMENT OF CONTRACTILE ROOTS IN GEOPHYTES

J. Galil
The University of Tel Aviv

ABSTRACT

Experiments and observations have been conducted on mature bulbs of *Leopoldia maritima* (Desf.) Parl., in order to determine the factors accountable for the production of contractile roots in shallow bulbs. It has been shown that the development of such roots does not depend on the length of the underground parts of leaves. It has also been proved that light, soil aeration, excessive heating of the soil and fluctuation in soil moisture are not among principal superficiality factors. The only factor responsible for stimulation of contractile root production appears to consist in rapid changes in ambient soil temperature. Accordingly, it has been possible to induce the production of strong contractile roots on deep-seated mature bulbs by intermittent heating of the soil, by means of hot water pipes.

INTRODUCTION

It is well known that the manner of growth and various morphological characteristics of geophytes are profoundly affected by the distance of the geophilous organ, such as a bulb or corm, from the soil surface. The depth of planting affects not only vegetative parts, but also reproductive ones (Galil 1953), e.g. the size of the geophilous organ, the extent of vegetative reproduction, or some properties of the inflorescence and the flowers.

The morphological and physiological modifications discernible in shallowly planted geophytes are undoubtedly due to factors associated with the shallowness of the geophilous organ. An attempt will be made in the following to evaluate these factors which will be referred to as superficiality factors.

Some of the pioneering work in this field was done by A. Rimbach, who investigated the effect of depth on the development of contractile roots in various plants. According to Rimbach (1895), the "depth perception" of a plant is related to the length of the leaves up to the soil surface. A shallow plant uses up a relatively small quantity of food materials for leaf growth. In such a plant, moreover, the period from the sprouting of the geophilous organ to the time when the new leaves start to assimilate carbon and begin to contribute to the plant's food supply,

Received June 3, 1958.

is comparatively short. A deep-seated plant, on the other hand, wastes much of its food reserves before its leaves become productive. The development of "motory" organs (in this case — contractile roots), which makes considerable demands upon the food supplies, is conditioned by the balance of storage materials in the geophilous organ. Thus only plants which have spent relatively little stored food before onest of assimilation are prone to develop " motory organs". The plant seems to be endowed with an aptitude to "measure" the depth of its geophilous organ by the amount of food material required to bring its leaves up to the surface of the soil. Rimbach's theory is certainly very interesting, but it should be viewed with due reserve, as it is not supported by any experimental evidence.

In his work on *Polygonatum multiflorum* Raunkiaer (1934), points out that the rhizome of this plant which grows horizontally within the appropriate soil layer, shows an upward or downward slant when it is too deep or too shallow, respectively. A modification of the normal transversal geotropism of the rhizome is thus induced by depth factors. In a series of experiments he concludes that none of the factors associated with the soil environment, such as the composition of the soil atmosphere, soil temperature or soil moisture, are responsible for changes in the direction of growth. Apparently a factor is involved which only comes into play when the plant has broken through the overlying soil layer. Raunkiaer also intimates that the plant somehow sounds its own depth by means of the distance covered by the leaves before they come into the light. However, unlike Rimbach, he attributes the regulation of depth to a stimulus transmitted by the green leaves with the onset of assimilation, rather than to the nutritional balance. Although Raunkiaer's assumptions are based on experimental data, they are not conclusive. No satisfactory account is given of the way in which the stimulus is formed and conveyed; it must also be said that the experimental evidence is by no means convincing.

According to Clapham (1945) who studied the direction of growth of *Polygonatum multiflorum,* light is the chief factor which affects the direction of growth of the rhizome in the soil.

Bennet-Clark and Ball (1951) investigated the diageotropic behaviour of the rhizomes of *Aegopodium podagraria.* They, too, concluded that light constitutes the factor responsible for the downward curvature of exposed rhizomes, while the high concentration of carbon dioxide in the soil results, in their opinion, in the upward trend of deep-seated rhizomes.

While many workers have dealt with a variety of problems bearing upon the action of contractile roots, no serious attempt has been made to single out the factor responsible for the formation of these roots in shallow plants.

Considering with reserve the various theories and assumptions put forward in the literature, we propose the following classification of the factors that can be suspected of bearing upon the behaviour characteristic of shallow plants.

1. *Distance factors.* Here belong all the factors associated with the growth of leaves up to the soil surface at the beginning of the season. They are operative only during the short period between sprouting and the onset of assimilation and give, in some way, expression to the distance between the geophilous organs and the soil surface. These are: (1) Length of leaf bases up to the surface of the ground. (2) Amount of food materials which the plant uses up for leaf production before the onset of assimilation. (3) Duration of the period between the sprouting of the geophilous organ and the emergence of leaves above ground.

2. *Soil factors.* This group comprises the factors which are conditioned by the depth of the geophilous organ and are related to the differences in the environment prevailing at different soil depths. These factors are effective during a prolonged period — practically during the whole growing season. They are: (1) Soil aeration. (2) Soil moisture and its fluctuations. (3) Soil temperature (minimum, maximum) and its fluctuation. (4) Light, penetrating into the soil, etc.

First, we shall have to ascertain to which group belong the factors associated with shallowness and then to isolate the component factors of the effective group, with a view to determine which of them are directly responsible for the characteristic behaviour of superficial geophilous organs.

EXPERIMENTAL MATERIAL

Of all the attributes of a superficial geophilous organ, the most striking, is the production of contractile roots. For the study of the factors responsible for the formation of contractile roots in superficially situated plants it was desirable to choose a plant in which the contractile roots differ conspicuously from feeding roots both in position and in appearance, with no occurrence of intermediate forms.

As a result of preliminary observations it became apparent that *Leopoldia maritima,* which occurs in light soils in the neighbourhood of Tel Aviv, is eminently suited for this study. *L. maritima* has a rounded bulb with no bulblets. The depth of the bulbs under natural conditions averages 70 mm. Plants with bulbs at ground surface, give rise to very strong, vertically descending contractile roots (Figure 1), easily distinguishable from the feeding roots. The former appear only under conditions of extreme shallowness, while a cover of 10-20 mm of soil is sufficient to preclude their formation. The experiments to be described were conducted during the years 1948-52 in the garden of the Biological Institute of Tel Aviv. The bulbs were planted in pots and large wooden boxes in sifted light sandy loam, under a variety of experimental conditions.

SPROUTING OF BULBS IN A DARK CHAMBER

Let us first ascertain whether the factors which induce the formation of strong contractile roots on superficial bulbs of *L. maritima,* are to be considered as distance or soil factors. As the time required to bring the leaves up to the surface is very

short in relation to the duration of the growth season which extends over several months, it may be assumed that the two groups of factors operate in succession : first the distance factors associated with the growth of leaves up to the onset of assimilation; and then — during the rest of the season — the various soil factors related to depth. In view of the definite time sequence, it should not be difficult to separate the two groups of factors.

Figure 1
Superficial plant with contractile roots.

In November 1948, fifteen selected bulbs of uniform size were planted in medium-size pots, in an extremely superficial position (the top of the bulb projecting about 2 mm above the surface). After thorough watering, the pots were placed in a dark chamber. The bulbs sprouted and produced long, pale shoots. The leaves remained tightly involute, just like leaves developing underground. After a fortnight the pots were removed from the dark chamber and planted out in a nursery bed. At the time of transplanting, the shoots measured in length between 40 and 130 mm. The leaves soon spread out and developed a normal green colour, and the plants did not in any way betray the fact that they had been grown for a time in total darkness.

In this way a separation of the two groups of factors was achieved : in spite of the great length of the leaves produced before the onset of assimilation, the plants remained during the whole season in an extremely superficial position. With regard to circumstances of early leaf production, viz. the amount of food reserves used up and the growth period before the onset of assimilation, the plants can be considered to all intents and purposes as deep-seated; however, in relation to the conditions which prevailed during the whole season, they were indisputably

superficial. When the plants were lifted in March 1949, it was found that all but one had developed a thick tuft of strong contractile roots.

The experiment described above was repeated in 1951. Although the shoots produced in the dark chamber were as much as 80-200 mm long, all the plants produced during the season a massive cluster of contractile roots. It follows that the formation of thick roots is not preconditioned by leaf length attained prior to the onset of assimilation, but is determined by soil factors associated with shallowness during the season.

It should be pointed out that while concerning leaf length, nutritional state, and duration of the pre-assimilation period — the experimental set-up can be regarded as analogous to the environment of deep-seated plants, there is an obvious lack of correspondence in regard to the resistance of the soil to the upward growth of leaves. This consideration led to a more elaborate experiment designed to test the results previously obtained.

DENUDATION EXPERIMENTS

Small wooden boxes 20 cm square and 12 cm high were prepared for these experiments. An easily detachable wooden frame 8 cm high was fitted on top of each box (Figure 2, 3). Seventy uniform bulbs (averaging 5 g in weight) of *Leopoldia maritima* were selected and planted five per box at the uppermost level of the lower tier, 80 mm below ground surface (Figure 2).

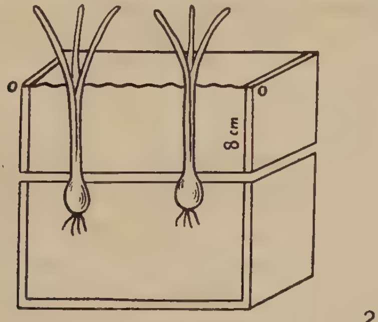


Figure 2
Denudation experiment.
Double tier box before denudation.

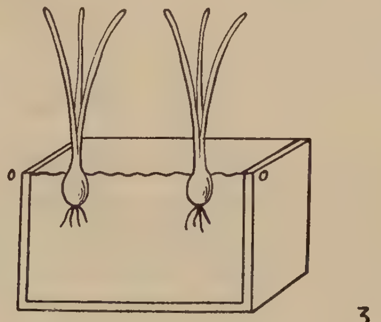


Figure 3
Denudation experiment.
After denudation.

After the onset of the rainy season when the bulbs sprouted and the leaves appeared above the ground, two boxes were bared by removal of the upper frames and by scraping away the soil lodged between the leaves, so that the tops of the bulbs became visible. Two additional boxes were bared each fortnight, the last pair being left as controls. In this way we obtained a series of plants which had sprouted at the beginning of the season as deep-seated plants, and were then subjected for various periods to the action of shallowness factors.

It may be noted in this connection that plants of *L. maritima* are particularly well suited for denudation experiments of this kind : the leaves appear above the ground almost simultaneously; they are not enclosed in sheats and, upon denudation, they spread out and turn green. Moreover, denudation leaves no marked traces, especially if the operation is performed on a cold rainy day.

Following denudation, the plants of *Leopoldia maritima* were subjected to regular observation, particular care being taken to ensure maintenance of superficiality throughout the season, with the tops of the bulbs protruding slightly above the ground. At the end of the season (April 13, 1951), the plants were carefully lifted, and the number of plants bearing contractile roots was determined for the ten plants bared on each date (Table I).

TABLE I

Development of contractile roots on bulbs subjected to different periods of denudation in Leopoldia maritima (1950-51 season)

Experiment set up: *November* 1950 *Final examination*: *April* 4, 1951

Date of denudation	Number of plants (out of 10) which formed contractile roots
Nov. 30, 1950	9 (roots very thick)
Dec. 17, 1950	9 (roots very thick)
Jan. 4, 1951	9 (roots thick)
Jan. 22, 1952	8 (roots thick); 1 (roots weak)
Feb. 11, 1952	8 (roots thick); 1 (roots just appearing)
Feb. 28, 1952	4 (roots thick); 3 (roots weak)
Control	None

The results of the denudation experiments, like those of the previously described dark chamber tests, show that the distance factors operative at the beginning of this season do not exercise a dominant effect on the formation of contractile roots in *Leopoldia maritima.* It is particularly noteworthy that plants which rose from the depth of 80 mm — the normal depth under natural conditions — produced strong contractile roots after having developed for a certain period under superficial conditions. The stimulus for formation of contractile roots could have been supplied in this case solely by soil factors.

The denudation experiments also provide information as to the minimum period required to induce the formation of contractile roots in a superficial plant. As indicated in Table I, plants bared at the end of February produced weak roots, while some did not produce contractile roots at all. It follows that extreme shallowness during March alone did not suffice to induce contractile root formation in all the plants. It should be noted that the winter of 1951 was characterized by few rains and relatively high temperatures. The month of March was unusually dry. In parallel observations made in the season of 1948-49, which was wet and

cold, no contractile roots developed on the bulbs which were bared at the end of January and at the beginning of February, as can be learnt from Table II.

TABLE II

Development of contractile roots on bulbs subjected to different periods of denudation in Leopoldia maritima (1948-49 *season*)

Experiment set up: *October* 1948 *Final examination*: *March* 3,1949

Date of denudation	Number of plants which formed contractile roots
Dec. 22, 1948	6 out of 8
Jan. 1, 1949	6 out of 16
Jan. 28, 1949	None out of 8
Feb. 2, 1949	None out of 8
Control	None

Thus it would appear that in cold and rainy seasons, strong contractile roots are produced only by those plants which have passed the early winter in a superficial position.

In order to determine more accurately the minimum period required to induce production of contractile roots in superficial plants, short-term denudation experiments were carried out during the 1950-51 season. All the plants came up from the depth of 60 mm, and they were bared during the season for varying periods. Some of the plants were again covered up after having been denuded during a fortnight, while others were maintained as superficial plants for a whole month (Table III).

TABLE III

Effect of length of denudation period on formation of contractile roots in Leopoldia maritima (1950-51 *season*)

Experiment set up: *October,* 1950 *Final examination*: *May,* 1951

Date of denudation	Number of plants which formed contractile roots
2 weeks (17.XII.50. — 1.I.51.)	1 out of 10
1 month (17.XII.50. — 22.I.51.)	5 out of 10

It can be seen that one month under conditions of superficiality was sufficient to induce production of contractile roots in a considerable proportion of the plants, whereas a fortnight did not suffice. Similar results were obtained in other seasons.

It should be borne in mind that these results can only serve as a general indication, since weather conditions vary considerably from year to year, and a fortnight at the beginning of the season is hardly comparable with a similar period at the end of the season. To secure more accurate results, it would be necessary to conduct experiments under controlled environment studies.

ISOLATION OF SOIL FACTORS

Now that we have eliminated the effect of distance factors and have ascertained that the factors responsible for inducing the development of contractile roots in mature superficial plants of *Leopoldia maritima* are associated with the condition of superficiality during the growing season, we have to determine which soil factors are operative.

Which of the soil factors are to be taken into consideration for producing contractile roots? The uppermost layer of the soil is well aerated and lighted, it warms up considerably during the day, and is subject to large fluctuations in temperature and in moisture content. Already at the depth of 5-10 cm below the ground surface, the increase of temperature is slight on rainy days and the daily fluctuations of temperature and moisture are comparatively small.

In the absence of facilities for the control of temperature and moisture, an attempt was made to isolate the soil factors by combinations of simple experiments. Two specific questions were formulated, on the assumption that their solution would help to clarify the problems associated with the effects of shallowness with which we are concerned. 1. How can development of contractile roots be induced in grown plants situated at the normal depth? 2. How can formation of contractile roots be prevented by various combinations of temperature, light, moisture and aeration in superficial bulbs?

Following a series of preliminary observations in 1949, large-scale experiments were conducted during the seasons 1949-50 and 1950-51. Full-grown bulbs of uniform size were planted at different depths and under a variety of conditions. Every combination of treatments was applied to ten bulbs in each season. In view of the similarity of results, the data for the two seasons will be pooled. The superficial bulbs were planted with their apices at 2 mm above ground surface, so as to ensure permanent depth control, while the deep-seated bulbs were planted at the normal depth of 60-80 mm.

OBSERVATIONS ON SUPERFICIAL BULBS

1. *Superficial planting in shade*

The bulbs were planted superficially in pots, on the shady north side of a large shed. The soil was wet and cool during the winter, and its temperature went up only slightly during the day. The bulbs developed normally and gave rise to leaves longer than usual. When the plants were lifted in March, it was observed that they had all developed strong contractile roots, although the formation of these roots occurred later than in plants exposed to the sun.

In order to obtain a quantitative estimate of the effect of shading on the formation of contractile roots, 60 bulbs were planted superficially in the season 1951-52, of which half were exposed to the sun and the other half shaded. Examinations were made on fixed dates, ten bulbs under each treatment being lifted at a time. The results are given in Table IV.

TABLE IV

Effect of shading on the formation of contractile roots in Leopoldia maritima (1951-52 *season*)

Date of lifting	Number of plants which formed contractile roots	
	Sun	Shade
25.XII.51	8 plants beginning to form contractile roots; 2 showing no sign of contractile roots	9 plants without contractile roots 1 beginning to form contractile roots
18.I.52	10 plants with contractile roots in initial stages of contraction	8 plants without contractile roots; 2 with contractile roots
12.II.52	10 plants with contractile roots in an advanced stage of contraction	10 plants with contractile roots; contraction not yet begun

Table IV shows that though the formation of contractile roots lags behind in shaded plants, it none the less takes place in the course of the season.

2. *Superficial planting in shade, with a covering of sawdust*

The bulbs were planted superficially and were covered with a layer of coarse sawdust 4 cm thick. The bulbs projected about half their heigh into the sawdust and were thus well aerated (owing to the rather large air-spaces between the particles of sawdust). The plants developed satisfactorily, and when they were lifted at the end of the season, not a single plant had formed contractile roots.

3. *Superficial planting in a glass case, in shade*

In a closed glass case (30×40×20 cm) a can with a perforated bottom was sunk into the soil in the middle of the case. The can was kept filled with water throughout the season (Figure 4). Owing to the glass walls and the percolation of water from the can, the soil in the frame was moist during the whole season. High air humidity was maintained during the entire experimental period, as could be deduced from the droplets of water collecting under the lid. The bulbs were planted superficially close to the walls of the case. It was ascertained at the end of the season that about 50 per cent of the plants had developed contractile roots rather late in the season; at the beginning of March the roots had still been rather short.

4. *Planting under an air space and a layer of sawdust, in shade*

Special boxes were constructed with a cover of wire-netting on top of which coarse sawdust was spread in a layer 3-4 cm thick (Figure 5). The wire-netting was placed some 8 cm above the soil in the box. The box with the wire-netting was sunk in the soil so that the top of the sawdust was level with the surface

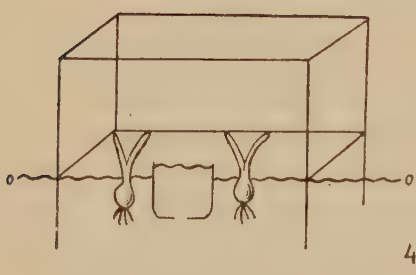
of the ground. The space underneath the sawdust was completely dark. The upper half of the bulbs protruded above the soil in the box, thus being in fact fully exposed to the air. After the beginning of the rainy season, the leaves rose above th sawdust, but the inflorescences failed to come up and they curled up within the air-space underneath the sawdust. When the plants were lifted at the end of the season, it was found that not a single one had developed contractile roots.

5. *Planting in a glass frame in the sun*

The frame resembled in every respect that used for the shade experiment (Figure 4). Here again high humidity was maintained throughout the season by means of a water-filled can. As opposed to the shaded counterpart, there were large diurnal fluctuations in the temperature of the air in the frame. The bulbs grew well and they all developed early in the season thick contractile roots which were much stronger than those of potted control plants.

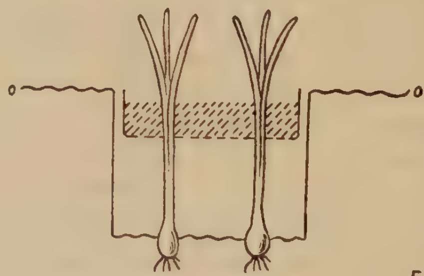
6. *Superficial planting below an air space and sawdust, in the sun*

The bulbs were planted in boxes, underneath an air space and a layer of sawdust as described for the parallel experiment in the shade (Figure 5). In the sun, the sawdust does not ensure complete darkness in the air-space underneath, and the plants find it difficult to come up. It was therefore necessary to employ special precautionary measures : at the time of planting the air-space was filled with sand, and only after the emergence of the plants the sand was carefully removed by way of a special opening at the side of the box. Normally developed plants were



4

Figure 4
Glass frame experiment (see text). 1 — Perforated can.



5

Figure 5
Air and sawdust isolation experiment.

secured by this procedure. Special care was taken to ensure that the bulbs be half-exposed in the air-space throughout the season. Examination at the end of the season showed that none of the ten plants in the box had developed contractile roots.

7. *Control*

The bulbs were planted superficially in pots in a normal fashion and were exposed to the sun. They all developed strong contractile roots.

Conclusions

From the results of the above experiments (1-7), the following conclusions can be drawn:

1. The aeration factor is of no importance. In the experiments 2 and 4, the bulbs were fully exposed to air or were kept in well aerated sawdust, and yet none developed contractile roots.

2. The development of thick roots on superficial plants grown in shade (exp. 1) shows that strong heating of the soil is not an essential condition for the development of contractile roots. The temperature of the top soil (measured at noon, 2 cm below surface) during the winter months did not exceed 12-13°C.

3. Moisture fluctuations (alternate wetting and desiccation) do not constitute a determining factor in the formation of contractile roots by mature plants: in the moist frame, in the sun (exp. 5), where high humidity was maintained throughout the season and the surface of the ground never dried up, strong roots were formed at an early stage.

4. It is clear that the tendency to produce contractile roots is stronger in the sun that in the shade.

Other observations made on plants of different ages invariably indicated stronger development of contractile roots in plants growing in the sun.

In the series of experiments outlined above it has only been partially possible to eliminate the formation of contractile roots in bulbs grown in a damp glass-frame in the shade. However, a moderately thick covering of sawdust was frequently sufficient to prevent their formation altogether. What effect does this overlying layer of sawdust exercise on the bulbs? As we have already seen, the stimulus responsible for the production of contractile roots cannot be attributed to increased aeration, high maximum of soil temperature *per se,* or fluctations in soil moisture content. Temperature fluctuations and light still remain to be considered.

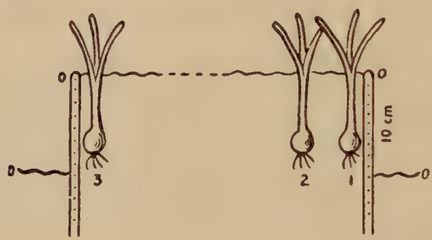
OBSERVATIONS ON DEEP-SEATED BULBS

Further information concerning the physiological causes of the production of contractile roots in *Leopoldia maritima* is supplied by observations on deep-seated bulbs. How can bulbs situated at the natural equilibrium depth be induced to form contractile roots? The fragmentary results of the previously described experiments, and more particularly the indications concerning the importance of rapid temperature changes — opened the way to further experimentation.

Growing bulbs close to glass plates with northern and southern exposure

For these experiments, a large frame was constructed (200×100×12 cm), with the two long sides made of wood, and the transverse sides consisting of long and

narrow glass plates. The frame was set up with the wooden walls facing east and west, and the glass plates exposed to north and south, respectively. The frame was filled right up to the rim with sifted light sandy loam. The southern glass plate was exposed to the sun during the whole day, while the glass plate facing north was in perpetual shade. Mature bulbs of *Leopoldia maritima,* selected for size, were planted in the frame 70-80 mm deep, ten bulbs per row, at various distances from the glass plates (Figure 6). At the beginning of the season the



6

Figure 6
Vertical section through a glass case.

glass plates were covered up with soil, to prevent penetration of light which might have interfered with the emergence of leaves in plants growing close to the plates. Upon the emergence of leaves, the soil cover was removed and the glass exposed.

Temperature readings were made several times during the season, both in and out of frame, mostly at the depth of 7 cm — at which the bulbs had been planted. A series of temperature records made at noon on December 17, 1950, which may be regarded as typical, gave the following readings :

Outside, 2 cm below surface, in sun	23°C.
Outside, 2 cm below surface, in shade	13°C.
In frame, 7 cm below surface, adjoining southern plate	28°C.
In frame, 7 cm below surface, 4 cm from southern plate	25°C.
In frame, 7 cm below surface, 40 cm from southern plate	18.5°C.
In frame, 7 cm below surface, adjoining northern plate	19°C.

It has been established that close to the southern plate there was a high rise in temperature during the day, followed by a rapid fall at night. The temperature fluctuations at this place were more pronounced than in the top soil layer outside the frame. At the northern end of the frame, at the depth of 7 cm, the temperature changes were also greater than at the same depth outside the frame. Although the sun's rays did not fall directly on the northern glass plate and there was no heat accumulation comparable with that at the southern end, the contact with the outside air resulted in a certain mid-day rise of temperature favoured by the low heat capacity of the glass.

Results

Row 1. Adjoining southern plate.

1950-51 and 1951-52 : All the bulbs (10) produced strong or rather strong contractile roots.

Row 2. 1 cm from southern plate.

1951-52 : Out of 10 plants, 6 produced contractile roots.

Row 3. 4 cm from southern plate.

1950-51 and 1951-52 : None of the plants produced contractile roots.

Row 4. 40 cm from southern plate.

1950-51 and 1951-52 : None of the plants produced contractile roots.

Row 5. Adjoining northern plate.

1950-51 : Out of 10 plants, one produced contractile roots.

1951-52 : Out of 10 plants, 9 produced contractile roots.

These observations throw some additional light on the problem under discussion:

1. Grown bulbs planted close to the southern plate (in one season—also those adjoining the northern plate) produced contractile roots at the depth of 80 mm, where no such roots are ever formed under normal planting conditions. In this way it was possible to induce production of contractile roots in deep-seated plants.

2. The distance factor — as expressed by the underground length of the leaves — exerts no influence on production of contractile roots, since plants which had come up from a depth of 80 mm and continued to develop at that depth throughout the season, produced contractile roots without any difficulty.

3. The relatively stronger and more rapid development of contractile roots at the south end of the frame, as compared with northern exposure, indicates that temperature evidently plays an important role.

4. The possibility that maximum temperature might exert a dominant influence is discounted by the formation of contractile roots at the northern end of the frame in the 1951-52 season, as also by the non-formation of such roots at a distance of 3-4 cm from the southern plate.

HEATING EXPERIMENTS

In the previous experiment in which bulbs were planted at a normal depth close to a transparent glass plate, the conditions under which the plants developed resembled those associated with superficial planting — not only as regards rapid temperature fluctuations, but also in possible exposure to light. It may therefore be asked if the latter factor does not exert some influence on the formation of contractile roots?

On the assumption that the conclusions previously drawn are correct, it should be possible to induce formation of contractile roots in plants growing at normal depth without the interposition of a glass plate, simply by raising soil temperature in some way.

Artificial heating (November 1953)

Two-inch iron pipes with upturned ends were buried in the soil before planting, 10 to 15 cm below the ground surface (see Figure 7). Mature, uniform bulbs were planted in upright position around the pipes. The bulbs were divided into lots consisting of ten bulbs each. Lot A was planted above the horizontal pipe; lot B by the side of the pipe, rather close to it; lot C was set out also laetrally but at a distance of 5 cm from the pipe. After planting, the bulbs were covered up to the ground level with 10-14 cm of sifted sandy loam.

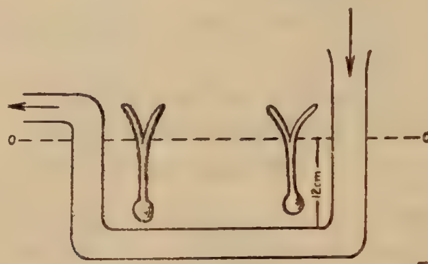


Figure 7
Installation for heating experiments.

The bulbs sprouted after rainfall and developed normally. When the plants were up and firmly established, soil heating was started by passing 9-10 litres of boiling water through the embedded pipe. Each operation began with displacement of the cold water which had been in the pipe since the previous day. The infusion of boiling water lasted from 15 to 20 minutes, whereupon the water was allowed to cool gradually. The soil heating was usually carried out in the morning, except on Saturdays. Fifty-four heatings were carried out during two consecutive months, between December 20, 1953, and February 20, 1954.

Results

In the middle of March, some three weeks after the last heating, the plants were carefully dug up and examined. The results were as follows:

1. The bulbs planted above the pipe (A) had suffered serious damage; most of them were yellow and desiccated. The bases of the bulbs were rotten and there were no live roots on them. The damage was undoubtedly caused by excessive heating, on account of the unduly close contact with the hot iron pipes.

2. The bulbs planted on the sides of the pipe (B and C) developed normally. The foliage was fresh and healthy and, on most plants, young inflorescences were found within the bunch of leaves. Since no apparent differences could be discerned between the bulbs planted quite close to the pipe and those planted at a distance of 5 cm, the two lots were considered as one group. Nine out of the 20 plants formed strong contractile roots, such as are normally formed only on very super-

ficially growing plants. The remaining eleven plants, though well developed, did not show any contractile root formation at the time of lifting. Control plants which had been planted at the depth of 10 cm at a distance from the pipe were well developed but, as might have been expected, did not form any contractile roots.

In order that these results be fully appreciated, it should be remembered that mature bulbs of *Leopoldia maritima* normally produce contractile roots only under conditions of extreme superficiality, when the tops of the bulbs protrude above ground surface. A layer of 10-15 mm of soil is enough to preclude completely the formation of thick roots.

The development of strong contractile roots on just about one half of the plants of the lots B and C — planted at normal depth or even deeper — excludes any possibility of light exercising an influence on the development of contractile roots. We are, therefore, fully justified in considering fluctuation in the temperature of the soil around the bulbs, due to periodic heating, as the controlling factor. Only by growing the bulbs under controlled conditions, with definite alternations of temperature and moisture, the precise identity and the relative importance of shallowness factors can be finally ascertained. Unfortunately, no such studies can be carried out for the time being in this country on a sufficiently comprehensive scale.

DISCUSSION

In the experiments described above, we succeeded by alterations in environmental conditions to induce the production of strong contractile roots on mature bulbs planted at relatively great depth and, under certain conditions, to prevent the formation of contractile roots on superficial bulbs. What conclusions can be drawn from these facts?

As already stated, the propensity to produce contractile roots is rather weak in *Leopoldia maritima,* and under ordinary conditions a 10-20 mm layer of soil above the top of the bulb is enough to prevent completely the formation of such roots. The appearance of contractile roots on bulbs of *L. maritima* provides a definite indication of intense action of factors involved in shallowness. Contractile roots are to be found on bulbs which are superficial in the physiological sense, whatever the actual distance from the surface of the ground. Conversely, superficial plants which owing to changes in conditions do not produce contractile roots, are physiologically deep-seated, even though their bulbs may in fact be protruding above the surface of the ground.

Under normal conditions, in a given soil, the properties of any geophyte vary with the depth of planting. The distance in centimetres of the geophilous organ from the soil surface provides a correct expression of the depth. However, when comparing plants from different habitats, or when dealing with plants growing under unusual conditions — the linear distance becomes devoid of its meaning. Thus two bulbs of *Leopoldia maritima* planted at the soil surface, of which

one is exposed to sun and the other one shaded, are mensurally at the same level, but the former is more strongly affected by shallowness factors and must therefore be considered as physiologically more superficial. Thus, if we compare one of the plants growing at the south end in our glass-plate experiment at a depth of 80 mm with a plant growing at the ground surface in a shaded glass frame, the latter is physiologically deeper than the former. Similar occurrences are found in nature, with plants growing in various exposures.

From the biological point of view, we are more interested in the physiological than in the physical depth, as it provides a measure of the degree of activity of superficiality factors which profoundly affect various important properties of geophilous plants.

The concept of physiological depth frees us from the narrow approach bound to linear measurements which has been current in studies of geophytes, and stresses the connection between depth and a certain complex of physiological factors. Although this complex is not readily amenable to examination and measurement, it provides the only faithful expression of the behaviour of the plant.

The distinction between linear and physiological depth is by no means of merely theoretical interest. We encounter in nature various instances in which this distinction is essential for the understanding of the life history and biological adaptations of geophytes, especially when we compare plants growing in different habitats, in sun and shade, and on various slopes in the mountains and hills.

ACKNOWLEDGEMENTS

My thanks are due to Prof. M. Zohary of the Department of Botany, as well as Prof. R. H. Oppenheimer, of the Faculty of Agriculture at the Hebrew University, who generously offered their advice, on various aspects of this work. I also wish to express my gratitude to Dr. N. Landau, for his conscientious and competent translation of the paper.

REFERENCES

1. Bennet-Clark, T. A. and Ball, N. G., 1951, The diageotropic behaviour of rhizomes, *J. exp. Bot., 2,* 169-203.
2. Clapham, A. R., 1945, Studies in the depth adjustment of subterranean plant organs. I. Raunkiaer's experiment on depth perception in *Polygonatum, New Phytol., 44,* 105-109.
3. Galil, J., 1953, Kinetics of geophytes, Doctor's Thesis, The Hebrew University (Hebrew).
4. Kirchner, O., Loew, E. und Schroeter, C., 1934, *Lebensgeschichte der Blütenpflanzen Mitteleuropas 1* (3), 861.
5. Raunkiaer, C., 1934, *The Life Forms of Plants and Statistical Plant Geography,* Clarendon Press, Oxford.
6. Rimbach, A., 1895, Zur Biologie der Pflanzen mit unterirdischem Spross, *Ber. dtsch. bot. Ges., 13,* 141-155.

SOME LICHENS ON OLIVE TREES IN ISRAEL*

I. Reichert and Margalith Galun
Faculty of Agriculture, The Hebrew University, Rehovot and Agricultural Research Station, Rehovot

ABSTRACT

Nineteen lichen species and varieties growing on olive trees in Israel were determined and described. Six of them are new species or new varieties.

INTRODUCTION

The following treatise deals with lichen specimens on olive trees collected in various districts in Israel: (1) Upper Galilee, including places of higher (500-700 m) and of lower (250-400 m) altitudes. (2) Mount Carmel (ca. 300 m). (3) Esdraelon Plain (altitude of ca. 70 m). (4) Jerusalem (800 m). Some of the specimens were collected many years ago in three places in Palestine: Near Nablus (500 m), Beit-Lehem (900 m), and Hebron (ca. 575 m), which are at present outside the boundaries of Israel.

Further studies of the lichen flora on olive trees in other regions of this country will certainly reveal the differences between the lichen associations, as correlated to the different ecological conditions.

All the measurements were taken from sections stained with cotton-blue. The colours in quotation marks were taken from Ridgway (1912).

1. **Lecidea euphorea** (Floerk.) Nyl. f. **euphorea** (Floerk.) Vain.

Nyl. Flora 70, 1881 p. 187, Lich. Paris 1896 p. 89 — *L. sabuletorum γ euphorea* Floerk. Berl. Magaz. 2, 1808 p. 311. — *L. euphorea* f. *euphorea* Vain. Lich. Fenn. IV, Acta Soc. Fauna et Flora Fenn. 57, 1934 p. 268.

On bark of old trees. SAMARIA: *Burqua* (near Nablus), ca. 500 m, 10.1942 *R.* JUDEA: Beit-Jala (near Beit-Lehem), 900 m, 9.9.1942 *R.*

Remarks: Vainio (1934), identifies *L. euphorea* with *L. glomerulosa.* He accepts only the name *L. euphorea* and rejects the name *L. glomerulosa,* which was accepted by Zahlbruckner (1925). Our specimens can be identified with the form *L. euphorea* f. *euphorea,* described by Vainio (1934), since they have a thicker and rugose thallus which has a positive (yellow) reaction with KOH. The other forms of this species do not possess these two features together.

---

* Abbrevations: *Collectors*: *A* - Z.Avizohar - Hershenzon; *G* - M. Galun; *P* - I. Peleg; *R* - I. Reichert.

2. **Lecidea olivacea** (Hoff.) Mass. (Figure 1).
Mass. Ric. Lich. Crost. 1852 p. 71. — *Verrucaria olivacea* Hoff. Deutschl. Fl. 2, 1796 p. 192.

On young twigs. UPPER GALILEE: Peki'in, ca. 600 m, 28.2.1950 *A;* Tarbiha, ca. 550 m, 1.3.1950 *A;* Mi'ilya, 500 m, 12.4.1957 *G.* LOWER GALILEE: Tsipori, ca. 250 m, 28.2.1950 *A.* JUDAEA: Beit-Aula (near Hebron), ca. 575 m, 23.9.1942 *R.*

Remarks: Our specimens fit the description given by Vainio (1934). The colour obtained with KOH was yellowish, similar to the finding of Vainio, which disagreed with Magnusson (1952) who obtained an orange reaction.

3. **Catillaria chalybaea** (Borr.) Mass. f. **ilicis** (Mass.) Vain. (Figure 2).
C. chalybeja Mass. Ric. Lich. Crost. 1852 p. 791. — *Lecidea chalybeia* Borr. Engl. Bot. Suppl. 1831 tab. 2687 f. 2. — *Lecidea ilicis* Mass. Mem. Lich. 1853 p. 124. — *C. chalybaea* f. *ilicis* Vain. Lich. Fenn. IV, Acta Soc. Fauna et Flora Fenn. 57, 1934 p. 430.

On young twigs. JUDAEA: Rachel's Tomb (near Beit-Lehem), ca. 750 m, 10.9.1942 *R.*

Remarks: Macroscopically very similar to *Lecania koerberiana* Lahm, which was even found on the same twig.

4. **Lecanora oleae** I. Reichert et M. Galun sp. nov. (Figure 3).

Thallus crustaceus, tenuis, granulosus, subareolatus, ochraeo-cinereus, KOH+ lutescens; hypothallo pallido.

Apothecia numerosa, dense aggregata, sessilia, 500 - 1200μ lata; disco plano vel leviter concavo, rufifusco, epruinoso; margine integro, opaco, rare leviter flexuoso, 75 - 100μ crasso; cortex gelatinosus, hyalinus vel flavorufescens, in parte superiore 10 - 15μ latus, in parte inferiore ad 45μ latus; excipulum 0 - 30μ latum, incoloratum, paraphysiforme, in parte superiore gelatinosum; hymenium 70-100μ crassum, cum I-IK+ caerulescens; hypothecium 45-75μ crassum, hyalinum; paraphysae gelatinosae, septatae, apice parum incrassatae et rufifusce coloratae; sporae octonae, hyalinae, ovideae vel ellipsoideae, non septatae.

Thallus crustaceous, thin, granulose, subareolate, cream-greyish, slightly darker than Ridgway's "Cream-Buff", KOH+ yellowish; with a paler coloured hypothallus.

Apothecia numerous, densely crowded, often deformated by pressure, sessile, 0.5 - 1.2 mm in diam.; disc plane, sometimes a little concave, reddish-brown, naked, surrounded by an entire, sometimes slightly flexuous, 75-100μ thick thalloid margin, concolours with the thallus; central part of the margin is nubilated by many very small crystals, surrounded by the gonidial layer, which is delimited by a thin, hyaline or yellowish-brown, hyphous, gelatinous cortex; cortex at the upper part 10-15μ, getting thicker up to 30μ, aside the hymenium, becoming still broader

at the lower part up to 45μ; exciple 0-30μ thick, hyaline, paraphysoid, upper part gelatinous; hymenium 70-100μ high, blue with I-IK; hypothecium hyaline, 45-75μ high, gonidial layer continuous beneath the hypothecium; paraphyses simple, 70-85μ × 2μ in size, gelatinous, straight, septate, with slightly broadened, brownish apices (forming the ca. 15μ thick pseudo-epithecium); spores 8, hyaline, simple, ovoid or ellipsoid, with many vacuoles, 12 - 15 μ × 6 - 7.5μ.

On trunk. UPPER GALILEE: Rameh (near Safed), ca. 400 m, 20.5.1931 *R.* JUDAEA: Talpioth (Jerusalem), ca. 800 m, 16.10.1933 *R.*

Remarks: This species belongs to the *L. allophana* type of the *L. subfusca* group, as defined by Poelt (1952). This type is characterized by a thin gelatinous cortex, becoming broader towards its lower part, and by the small crystals (1-6μ) filling the cortex and the medulla.

Our species presents the above-mentioned features and resembles most closely the new species *L. laevis* described by Poelt (1952). It is similar to the latter by its morphology and anatomy and its geographical distribution, as it is limited to South European and Mediterranean habitats. It differs, however, from *L. laevis* by: 1. distinct brighter coloured hypothallus; 2. non-glistening thalloid margin; 3. septate pharaphyses; 4. creamy colour of the thallus as compared with a greyish one of *L. laevis.*

5. **Lecanora hageni** Ach. f. **coerulescens** Flag.
Ach. Lichenogr. Univers., 1810 p. 367. — *L. hageni* f. *coerulescens* Flag. Mém. Soc. d'Emulat. Doubs, 1896 p. 283.

On young twigs. UPPER GALILEE: near Tarshiha, 500 m, 12.4.1957 *G.* ESDRAELON PLAIN: Merhavya, 70 m, 21.7.1943 *A.*

6. **Lecanora hageni** Ach.var. **inspersa** I. Reichert et M. Galun var. nov. (Figure 4).

Resembles in most features the type species, according to Harmand (1913), and f. *coerulescens* as identified by us. It differs from them by the following features:

Latus superius thalli marginis (15-30μ × 30-40μ) granulis parvis inspersum. Paraphysae uniformes, crassae (1.5μ) vel apice abrupte incrassatae ad 3μ, colore destitutae.

1. The upper part of the thalloid margin is a 15-30μ high and 30-40μ thick layer of very small colourless granules (these are perhaps the granules forming the whitish pruina). 2. The paraphyses are 1.5μ thick, without a brownish cap, they are of the same thickness from the bottom to the tips or are thickening abrupty up to 3μ at the apices. It resembles the type species and differs from

f. *coerulescens* by having a whitish pruinose disc.

On young twigs. ESDRAELON PLAIN: Merhavya, 70 m, 21.7.1943 *A.*

7. **Lecania koerberiana** Lahm
Lahm apud Körb. Parerg. Lichen. 1859 p. 68.

On young twigs. JUDAEA: Rachel's Tomb (near Beit-Lehem), 750 m, 10.9.1942 *R.*

8. **Parmelia glabra** (Schaer.) Nyl.
Nyl. Flora 4, 1872 p. 548. — *Parmelia olivacea* var. *corticola* a. *glabra* Schaer. Lich. Helvet. Spicil. Sect. 10, 1840 p. 466.

On bark of old trees. UPPER GALILEE: Rameh (near Safed), ca. 400 m, 6.1.1935 *P*, 12.4.1957 *G.*

9. **Parmelia scortea** Ach. var. **scortea** (DC.) Maas G. (Figure 5).
Ach. Method. Lich. 1803 p. 215. — *Imbricaria quercina* var. *scortea* DC. in Lam. et DC. Flore Franc. ed. 3, vol. 6, 1815 p. 187. — *P. scortea* var. *scortea* Maas G. Blumea 6, No. 1, 1947 p. 147.

On trunk of an old tree. UPPER GALILEE: Rameh, 400 m, 12.5.1957 *G.*

Remarks: Measurements were taken from one apothecium only.

10. **Ramalina duriaei** (De Not.) Jatta
Jatta, Monogr. Lich. Ital. Meridion. 1889 p. 83. — *Ramalina pollinaria* var. *duriaei* De Not. Giorn. Botan. Ital., 1, parte I, 1846 p. 216.

On twigs. UPPER GALILEE Mi'ilya, ca. 500 m, 12.4.1957 *G.*

11. **Ramalina fastigiata** Ach. (Figure 6).
Ach. Lichenogr. Univers. 1810 p. 603.

UPPER GALILEE: Mi'ilya, ca. 500 m, 12.4.1957 *G.*

12. **Caloplaca esdraelonensis** I. Reichert et M. Galun sp. nov. (Figure 7).

Thallus crustaceus, griseus, KOH+ lutescens, orbicularis, 1 - 2 cm in diam., centro areolato, areolis planis, parvissimis, circumferentia granulari; hypothallo nullo vel praesente et atrocinereo.

Apothecia in centro aggregata, sessilia, 300 - 600μ lata; disco rufifusco, KOH+ purpureo, concavo vel plano, margine 90 - 120μ crasso, prominente, circumcluso; hypothecium incolorum, 45-75μ crassum; epithecium granulosum aurantiacum; excipulum incolorum; paraphysae articulatae, nonnumquam ramosae, apice graduatim incrassatae; sporae octonae, placodiomorphae, hyalinae, subglobosae vel ellipsoideae.

Thallus crustaceous, orbicular, 1-2 cm in diam., 90-100 μ thick, built in the centre of irregular, plane, very small, about 0.04 mm in diam. areoles, and gra-

nulose at the circumference, dark grey, KOH+ yellowish; hypothallus not always present, greyish-black; thallus built of an hyaline, paraplectenchymatous, 15-30 μ thick cortex, covered by a very thin, greyish, crystalloid layer; gonidial layer more or less continuous, about 70 μ thick; medulla unseen.

Apothecia crowded in the centre, sessile, 300-600μ in diam.; disc reddish-brown, KOH+ purple, at first cup-shaped or concave, getting plane when mature, surrounded by a prominent, 90-120 μ thick thalloid margin, concolorous with the thallus; marginal cortex hyaline, cellular, cells 3-7.5 μ in diam., 9-15 μ thick at the upper part, 35-46μ thick laterally and beneath the apothecia; gonidial layer, thick, dense, continuous beneath the hypothecium; hypothecium hyaline, 45-75 μ high; hymenium hyaline, 60-75 μ high, covered by a granulose, 10-20 μ thick orange epithecium; exciple hyaline, lower part 6-15 μ thick, built of interwoven ca. 1.5μ thick hyphae,, with elongated 4.5-6 μ long cells; upper part 30-35 μ thick, built of roundish cells, similar to the cortical cells; paraphyses hyaline, septate, sometimes branched, ca. 1 μ thick, getting gradually thicker towards the ends, up to 2 μ; spores placodiomorphic, hyaline, subglobose or ellipsoid, 10.5-12 $\mu \times$ 7.5-9 μ, with a 6-7.5 μ long isthmus.

On twigs. ESDRAELON PLAIN: Merhavya, ca. 70 m, 22.7.1943 *A.*

Remarks : This species resembles the *ferruginea* group by having a reddish-brown disc, but differs from it by showing a yellowish reaction with KOH.

13. **Caloplaca pyracea** Th. Fr. (Figure 8).
Th. Fr. Kgl. Svensk. Vetensk.-Akad. Handl. 7, No. 2, 1867 p. 25.

On twigs. UPPER GALILEE: Rameh (near Safed), ca. 400 m, 20.5.1931 *R;* Mi'ilya, ca. 500m, 12.4.1957 *G;* LOWER GALILEE: Tsipori, ca. 250 m, 28.2.1950 *A;* SAMARIA: Burqua (near Nablus), ca. 500 m, 28.2.1931 *R.* JUDAEA: Beit Aula (near Hebron), ca. 575 m, 23.9.1942 *R.*

14. **Buellia canescens** (Dicks.) De Not. (Figure 9).
De Not. Giorn. Botan. Ital., 1, parte I, 1846, p. 197. *Lichen canescens* Dicks. Fasc. Pl. Cryptog. Brit., 1, 1785, p. 10.

On twigs. UPPER GALILEE: Meron, ca. 700 m, 29.9.1942 *R;* Tarbiha, ca. 550 m, 1.3.195[illegible] *A;* Tarshiha, ca. 500 m, 12.4.1957 *G.* LOWER GALILEE: Tsipori, ca. 250 m, 28.2.1950 [illegible] SAMARIA: Burqua (near Nablus), ca. 500 m, 20.5.1931 *R.* JUDAEA: Beit Jala (near Beit-Lehem), ca. 900 m, 8.9.1942 *R.*

Remarks : B. canescens has been found in the warmer localities of Western Euro[illegible] and in the Mediterranean countries. It requires great warmth, as pointed out [illegible] Almborn (1948). In Scandinavia it occurs only in warm habitats, either on t[illegible] where the temperature is higher than in the lower habitats, or on stone, especially on cement walls, which are mostly heated by the sun.

Almborn has found all or most of the *B. canescens* collections examined by him and coming from various countries, to be sterile. The fact that our specimens were mostly fertile, indicates that *B. canescens* is a thermic lichen. It would, therefore, be better to say, xerothermic, as all the collections in Israel came from the Upper Galilee, Samaria and Judaea, where the relative humidity is low and desiccating winds prevail.

15. **Rinodina magnussoniana** I. Reichert et M. Galun sp. nov. (Figure 10).

Thallus tenuis, maculas distinctas vel confluentes formans, minute granuloso-verrucosus, cinereo-olivaceus; hypothallo atro-cinereo.

Apothecia numerosa, adnata, 300-700 μ lata; disco nigro, plano vel rare convexo, leviter pruinoso, margine ca. 60 μ crasso, irregulariter crenulato circumcluso; excipulum 7-16 μ crassum, paraphysiforme; hypothecium 75-90 μ crassum, hyalinum vel lutescens; hymenium 90-100 μ crassum; epithecium ca. 12 μ crassum, brunneum; paraphysae laxae, nonnumquam ramosae, apice incrassatae et rufofusce coloratae; sporae octonae, fusco-virescentes.

Thallus very thin, forming patches or confluent, minutely granular-verrucose and irregularly cracked. "Light Greyish Olive" or "Greyish Olive", KOH+ yellow, sometimes delimited by a blackish-grey hypothallus.

Apothecia numerous to crowded, adnate, 300-700 μ in diam.; disc usually blackish and plane, sometimes convex, slightly pruinose, surrounded by a slightly irregularly crenulate, ca. 60 μ thick thalloid margin, concolorous with the thallus, built mainly of gonidia, delimited by a brownish paraplectenchymatous cortex composed of 2-3 cell rows, the inner two are arranged vertically, 3-4.5 × 3-4 μ in size, exterior cells are smaller, 1.5-2 μ, roundish or longish-horizontal, reaching as far as surface or covered by an amorphic layer; gonidial layer only lateral, not exceeding beneath the hypothecium; exciple 7-16 μ thick, paraphysoid, confluent with the hypothecium; hypothecium hyaline or yellowish, 75-90 μ high; hymenium 90-110 μ high, covered by a dark brown, ca. 12 μ thick epithecium; paraphyses lax, 1.5 μ thick, apices swollen up to 3-3.5 μ, tips covered by a brown cap, sometimes branched at the upper part; 8 spores, usually in two rows, 15-18 μ × 7.5-9 μ in size, usually greenish-brown with thickened, 3.5-4 μ, convex apical spore walls, and almost angular loci, but many greenish spores with straight apical walls, and brown spores with roundish loci were also observed.

On twigs. LOWER GALILEE: Tsipori, ca. 250 m, 28.2.1950 *A.* SAMARIA: Burqua (near Nablus), ca. 500 m, 10.9.1942 *R.*

16. **Rinodina carmeli** I. Reichert et M. Galun sp. nov.

Thallus inconspicuus, circumferentia minute granuloso-verrucosa, centro crebre fissurato, nigro-olivaceo; hypothallo indistincto.

Apothecia contigua, adnata, 400-800 μ lata; disco nigro, pruinoso, plano vel rare leviter convexo, margine prominente, irregulariter crenulato circumcluso; excipulum indistinctum vel 6-30 μ crassum et paraphysiforme; hypothecium hyalinum vel pallide lutescens, 45-65 μ crassum, cum I-IK+ violesceum; hymenium 100-125 μ crassum, cum I-IK+ cyaneum; epithecium ca. 12 μ crassum, fuscum; paraphysae laxae, apice incrassatae et fusce coloratae; sporae octonae, prius virides, demum fuscae, apice incrassatae, septo tenui.

Thallus inconspicuous, thin to very thin, minutely granular, verruculose (mainly at the periphery), and cracked at the centre, "Olivaceous Black" (Almborn 1948), KOH+ yellowish; no hypothallus visible.

Apothecia contiguous, adnate, 400-800 μ in diam.; disc blackish, pruinose, usually plane, sometimes slightly convex, surrounded by a slightly prominent, irregularly crenulate, 75-150 μ thick thalloid margin, very often deformated by pressure, concolorous with the thallus; margin built mainly of gonidia, surrounded by a thin, 5-12 μ thick, brownish, paraplectenchymatous cortex, composed of 4-5 cell rows, inner rows are formed of roundish or longish horizontally arranged cells 3-9 × 3 μ in size, external cells are smaller, about 1.5 × 2 μ; exciple indistinct, or very thin, ca. 6 μ thick and not reaching the height of the hymenium, or sometimes even broadened up to 30 μ towards the edge, paraphysoid and confluent with the hypothecium; hypothecium hyaline or slightly yellowish, 45-65 μ high, violet with I-IK; hymenium 100-125 μ high, dark blue with I-IK, covered by a brownish, ca. 12 μ thick epithecium; paraphyses lax with thickened (3-3.5 μ) brownish apices; spores 8, 15-18 μ ×7.5-9 μ in size, with thin septum and side walls, and thickened (3-3.5 μ) apical walls, at young stage greenish with straight or slightly convex apical spore walls getting brown and loci roundish with age, septum without porus.

On twigs. MOUNT CARMEL: Umm-a-Zinat, ca. 300 m, 18.2.1954 *A.*

Remarks: Magnusson (1947) has described in detail *Rinodina oleae* Bagl., so that together with our two new species, three *Rinodina* species have been found on olive trees.

Our two species differ from *R. oleae* mainly by their positive reaction of the thallus with KOH. From Magnusson's description it seems that *R. oleae* has a lighter coloured and somewhat thicker thallus than our two species.

There is a resemblance between the hypothallus of *R. oleae* (Magnusson 1947) and *R. magnussoniana,* but in *R. carmeli* no hypothallus is observed.

According to Magnusson's description of *R. oleae,* it has no exciple, whereas *R. magnussoniana* always has a distinct exciple, and in *R. carmeli* it is indistinct only in some apothecia.

Another microscopic difference between *R. oleae* and our two species is the structure of the marginal cortex. In *R. oleae* there is no cortex at the upper part of the margin, or it is 3-4 μ thick, without distinct cells, whilst in both our described

species there is a very distinct paraplectenchymatous cortex of the margin.

The following is a small key to the three *Rinodina* species found on olive trees :

A. Thallus KOH — *R. oleae*

B. Thallus KOH +

a. Thallus greenish-black, apothecia contiguous, marginal cortex of 4-5 cell rows: *R. carmeli.*

b. Thallus greyish-olive, apothecia numerous, marginal cortex of 2-3 cell rows: *R. magnussoniana.*

17. **Physcia biziana** (Mass.) A. Zahlbr. var. **granuligera** A. Zahlbr. (Figure 11). A. Zahlbr. Oesterr. Bot. Zeitschrift 51, 1901 p. 349. — *Squamaria biziana* Mass. Miscell. Lich. 1856 p. 35. — *Physcia biziana* var. *granuligera* A. Zahlbr. Oesterr. Bot. Zeitschrift 55, 1905 p. 66.

On trunk and twigs. UPPER GALILEE: Maghar-um-Chet, ca. 400 m, 18.2.1954 *A.*

18. **Physcia leptalea** (Ach.) DC.
DC. in Lam. et DC. Flore Franc., ed. 3., vol. 2, 1805 p. 395. — *Parmelia leptalea* Ach. Method. Lich. 1803 p. 198.

On trunk and twigs. UPPER GALILEE: Rameh, ca. 350 m, 20.5.1931 *R.*

19. **Physcia leptalea** (Ach.) DC. var. **granulosa** I. Reichert et M. Galun var. nov. (Figure 12).

Thallus centro granuloso; margo thallinus interdum granulosus.

Thallus centre granulose; margin of the apothecia getting sometimes granulose too.

Appearing together with the type.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Dr. R. A. Maas Geesteranus for the final determination of *Parmelia glabra, Ramalina fastigiata* and *Ramalina duriaei.* They are also indebted to Dr. Z. Avizohar-Hershenzon for her kind assistance, and to Prof. H. R. Oppenheimer for revising the Latin text.

REFERENCES

1. ALMBORN, O., 1948, Distribution and ecology of some South Scandinavian lichens, *Bot. Not. Lund,* 169-178.
2. HARMAND, J., 1913, *Lichenes de France, 5,* p. 1014 Libr. des Sci. Nat., Paul Klincksieck, Paris.
3. MAGNUSSON, A. H., 1947, Studies in non-saxicolous species of *Rinodina, Sartrych Meddel., Göteborgs bot. Tradg., 17,* 290-291.
4. MAGNUSSON, A. H., 1952, Key to the species of *Lecidea* in Scandinavia and Finland. II. Non-saxicolous species, *Svensk. bot. Tids., 46,* 319.
5. POELT, I., 1952, Die *Lecanora subfusca*-Gruppe in Süddeutschland, *Ber. bayer. bot. Ges., 29,* 64.
6. RIDGWAY, R., 1912, *Colour Standards and Colour Nomenclature,* A. Hoen et Co., Baltimore, Md.
7. VAINIO, E. A., 1934, Lichenographia Fennica IV, *Acta Soc. Fauna et Flora Fennica, 57,* 268, 271.
8. ZAHLBRUCKNER, A., 1925, *Catalogus Lichenum Universalis, 3,* 588, Gebr. Borntraeger, Leipzig.

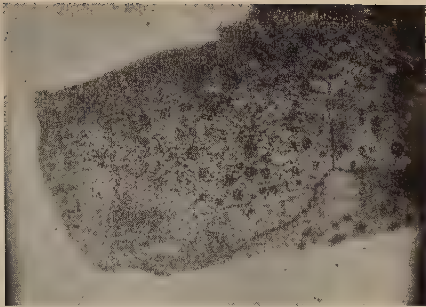


Figure 1
Lecidea olivacea (Hoff.) Mass.
× 3

Figure 2
Catillaria chalybaea (Borr.) Mass.
f. *ilicis* (Mass.) Vain. × 6

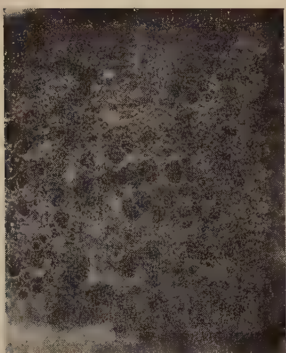


Figure 3
Lecanora oleae I. Reichert et M.
Galun sp. nov. × 3

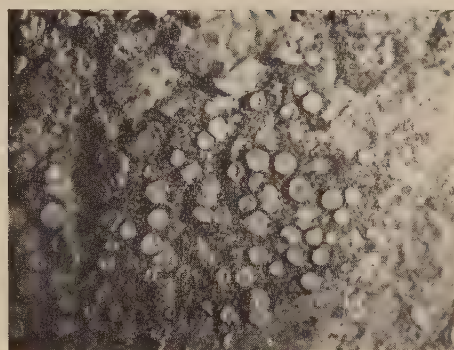


Figure 4
Lecanora hageni Ach. var.
inspersa I. Reichert et
M. Galun var. nov. × 6

Figure 5
Parmelia scortea Ach. var. *scortea*
(DC.) Maas G. × 3

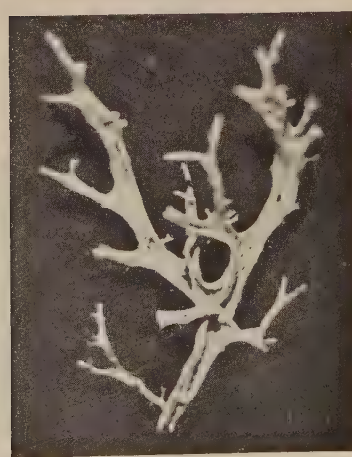


Figure 6
Ramalina fastigiata Ach. × 3

Figure 7
Caloplaca esdraelonensis
I. Reichert et M. Galun sp. nov.
× 6

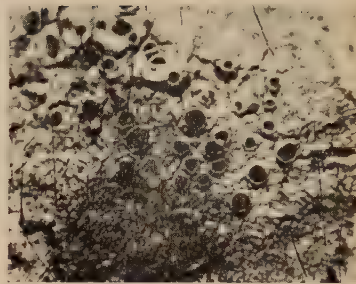


Figure 10
Rinodina magnussoniana
I. Reichert et M. Galun sp. nov.
× 6

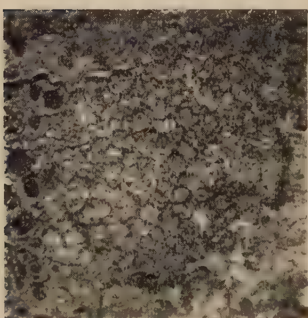


Figure 8
Caloplaca pyracea Th. Fr. × 6

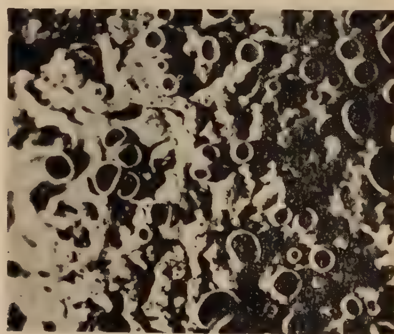


Figure 11
Physcia biziana (Mass.) var. *granuligera* A. Zahlbr. × 3

Figure 9
Buellia canescens (Dicks.) De Not.
× 3

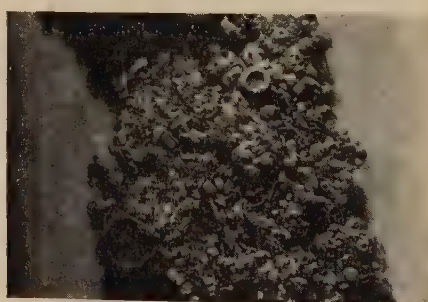


Figure 12
Physcia leptalea (Ach.) DC. var. *granulosa* I. Reichert et M. Galun var. nov. × 3

A STUDY OF AIR-BORNE FUNGI IN ISRAEL

Rivka Barkai-Golan *
Department of Botany, The Hebrew University of Jerusalem

ABSTRACT

Petri-dishes with Czapek-agar were exposed for 15 minutes each every second day during three successive years (June 1950 – June 1953) in Tel-Aviv and during one year in five other locations in Israel.

A seasonal variation in the number of fungal spores in the air was found. During the winter months there were only few spores, while their number increased during the rest of the year.

The most frequently found air-borne spores in the various localities were: *Hormodendrum* (35-65% of the total catches); *Alternaria* (6-11%); *Penicillium* (5-14%); *Aspergillus* (2.5-9%); Miscellaneous fungi (13-29%) of which the most common were: *Stemphylium, Fusarium, Monilia, Mucor, Rhizopus, Epicoccum, Trichoderma, Botrytis, Helminthosporium, Pullularia, Phoma, Torula,* etc.; and the group of Actinomycetes (about 8%).

Collections were made also from an aeroplane at various altitudes up to 2000 metres. At altitudes up to 300 metres large numbers of fungi were found, greatly decreasing towards an altitude of 1000 metres. Above 1000 metres, spores occurred only rarely.

Spores were collected over the Mediterranean Sea on shipboard at various distances from shore. No area was found to be entirely free of air-borne spores, and the species found over the Mediterranean were identical with those found in the air over land.

INTRODUCTION

Air-borne spores constitute a flora or a "spora" (Gregory 1952) rich in genera and species.

The air-borne spores are of great importance in the problems of allergy, for they are among the respiratory allergens. For the last twenty years doctors and mycologists have shown an increasing theoretical and practical interest in the question of air-borne spores. Surveys of the fungal spore content of the air have been carried out in different parts of the world as a first step in the investigation of the problems of respiratory allergy.

As up to 1950, there had been practically no investigation of the air-borne fungi in Israel, it seemed of interest to conduct a systematic study. This study was carried out from June 1950 to July 1954.

METHODS

The culture plate method was chosen as it was found to be the most satisfactory for differentiation between genera and species of the air-borne fungi.

---

* Present address: Agricultural Research Station, Rehovot.

Received April 9, 1957.

This method is based on exposing Petri-dishes containing a suitable culture medium, and examining the colonies developing from the spores after incubation. The culture medium in the plates was generally Czapek-agar and only in a few cases potato-dextrose-agar. The plates were exposed horizontally for 15 minutes. Cultures were examined after 4-10 days' incubation at room temperature as follows : a) the total number of colonies was counted; b) fungi were identified; c) the frequency of occurrence of the most common fungi was recorded.

Air-borne spores were collected from : a) various localities in the country, b) various altitudes, by aeroplane, and c) from the air above the sea, at various distances from shore.

I. THE DISTRIBUTION OF AIR-BORNE FUNGI AT HABITATION LEVEL OVER LAND

A. *In Tel-Aviv*

A systematic survey was made in Tel-Aviv, a coastal town (latitude N. 32°4′, longitude E. 34°47′). The average maximum temperature is 29.7°C in August; average minimum temperature is 8.5°C in January. Average maximum relative humidity is 84% in July-August, minimum is 70% in November-January.

Two surveys of fungal spores were made in Tel-Aviv : a) a survey of hourly distribution and b) a survey of annual distribution.

Hourly distribution. Two culture plates were exposed simultaneously every hour during 48 successive hours. Records of temperature, relative humidity, and wind velocity were taken for each exposure at its site.

The results of such exposures on 3-5 August 1954 are given in Figure 1. Other diagrams from a similar survey on other dates, were of the same character.

The diagrams show that night collections resulted in a few colonies, while day collections gave a much higher number of colonies. The maximum and minimum number of colonies, however, is not related to a definite hour of day or night. The diagram also indicates a correlation between wind strength at the time of exposure and number of colonies counted.

Annual distribution. Collections were made every second day at 9 a.m., for three successive years (June 1950 — June 1953). Two plates were exposed simultaneously to each direction, on the railing of a roof at about 40 metres altitude. We used the meteorological records made by the Meteorological Service of the Ministry of Transport and Communications in Tel-Aviv, which is situated at a distance of about 500 metres from the site of exposure.

Results were summed up in weekly averages (per plate) of the total number of colonies and of the number of most frequently found genera (Figure 2).

The diagrams show a characteristic course during the three years of survey. During the months April-November, a large number of colonies was counted. A marked drop in the number of colonies occurred in December (late December 1951 and early December 1952) or in January (early January 1951). During the winter months the number of colonies remained low till March (late March 1951 and

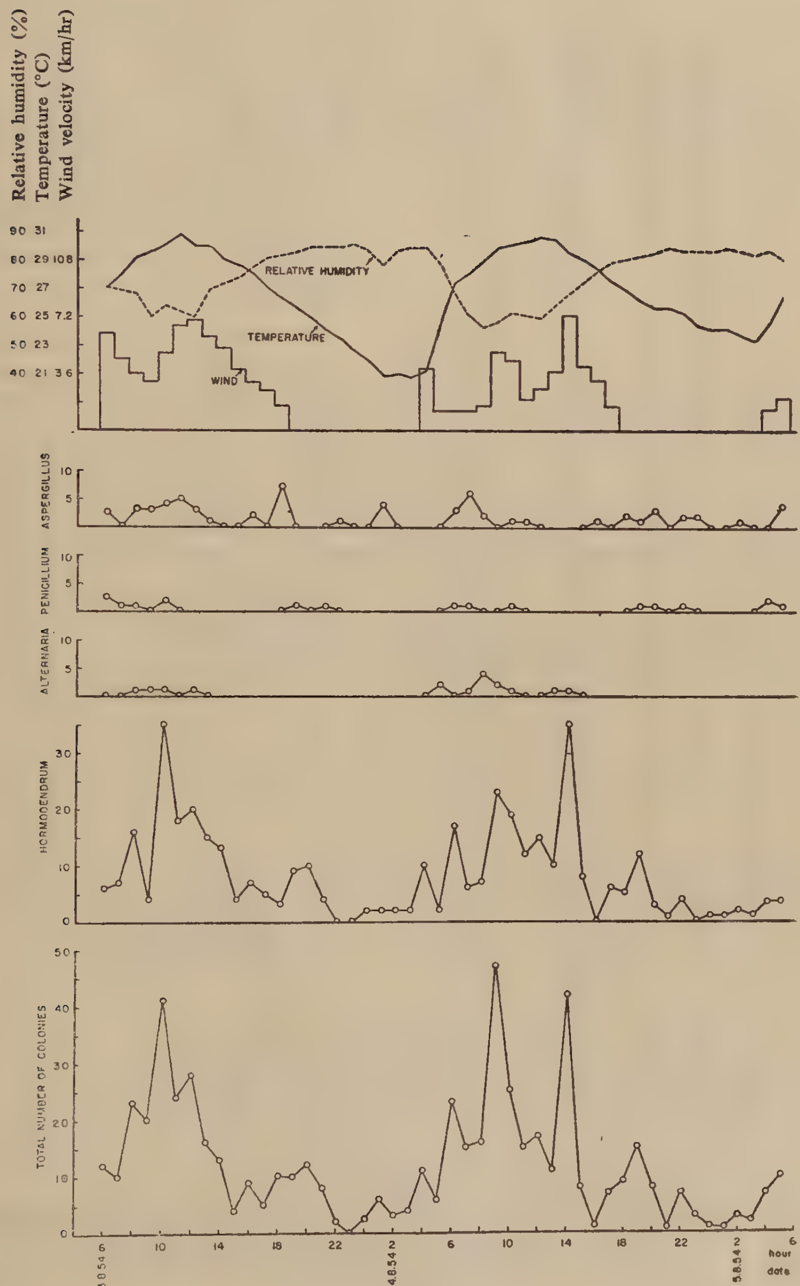


Figure 1

Hourly distribution of air-borne fungi in Tel Aviv (August 3-5, 1954).

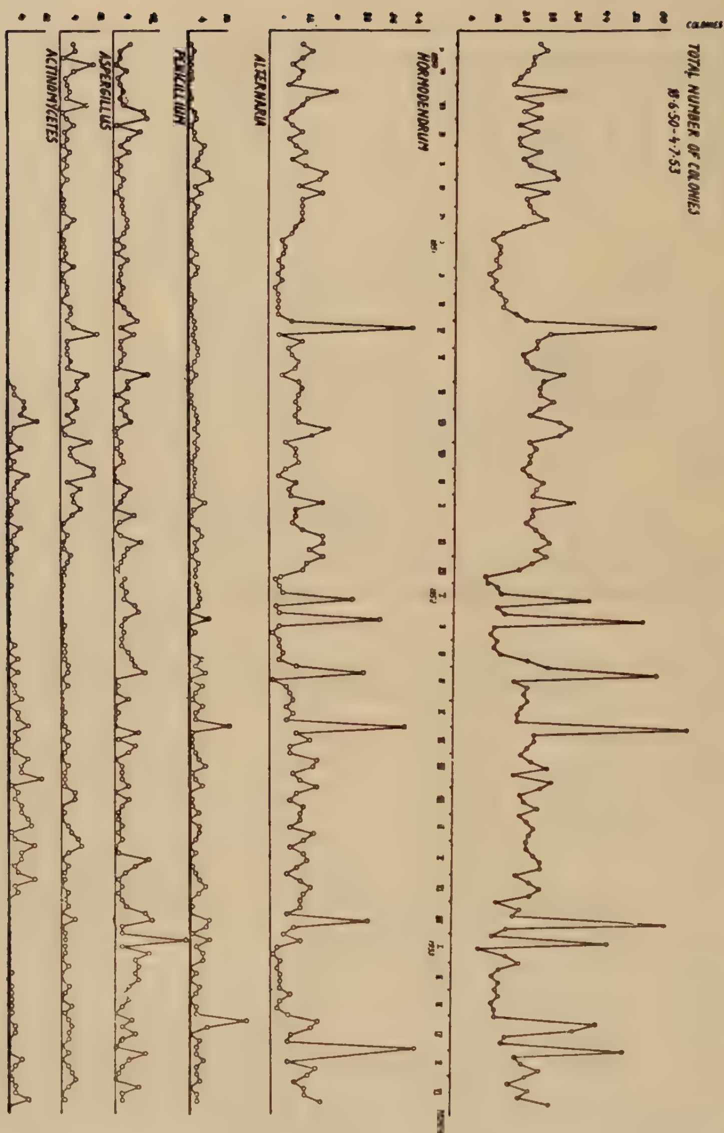


Figure 2

Annual distribution of air-borne fungi in Tel Aviv (Weekly averages of colonies) (June 1950 — July 1953).

1952) or April (early April 1953). From April onwards their number began to rise and remained high during spring, summer and autumn.

The annual diagrams show several peaks of unusually high readings in the number of colonies. These peaks were caused by strong winds which prevailed at the time of exposure. Peaks in April 1951 were due to strong dry east winds (6E)*. In January, February, April, June and December 1952, peaks were caused by west (4W), southwest (4SW), northwest (3NW) north (3N) and southwest (5SW) winds respectively, and in January and April 1953, by southwest (4SW) and northwest (3NW) winds respectively.

The marked drop in the number of colonies at the end of December 1951 was due to exposures made after rain.

The data show that :

a) Fungi are permanently found in the air.

b) There is a seasonal variation in the number of fungal spores in the air; during winter, which lasts only from December to March, there are relatively few colonies, the average being 12-20 colonies per plate; the number rises to a peak in summer and autumn, to an average of 22-28 colonies per plate.

c) This seasonal variation appeared to be in correlation with the mean temperature, since low numbers appeared to occur mainly during cold months.

d) There is a marked relation between wind strength at the time of exposure and number of spores which settle on the Petri-dishes. With a very strong wind the number of colonies on the plates increases considerably up to several hundreds on one plate.

e) No influence of the direction of the wind on the quantity of the spores has been found.

f) Rain tends to decrease the number of spores collected.

g) The air-borne fungi most frequently found were of the following genera and groups : 1. *Hormodendrum*, 2. *Penicillium*, 3. *Aspergillus*, 4. *Alternaria*, 5. "miscellaneous" fungi, 6. Actinomycetes, 7. yeasts.

B. *In other localities in Israel*

Five localities were chosen representing different climatic conditions : Mount Ca-na'an, 934 metres alt. representing Upper Galilee; Ashdot-Ya'aqov, a settlement in the Jordan Valley, about 200 metres below sea level; Haifa, 85 m alt. on the slopes of Mount Carmel; Jerusalem, about 800 m alt., representing the Judaean Mountains, and Beersheva, 270 m alt., representing the Northern Negev.

In all five stations exposures were made at habitation level, i.e. in Jerusalem and Beersheva on roofs of houses 20-40 m high, and in the other three localities in courtyards, on tables 1-1.5 metres above ground.

* According to Beaufort scale.

Plates were exposed twice a month from May (1951) to April (1952). The results are given in Figure 3.

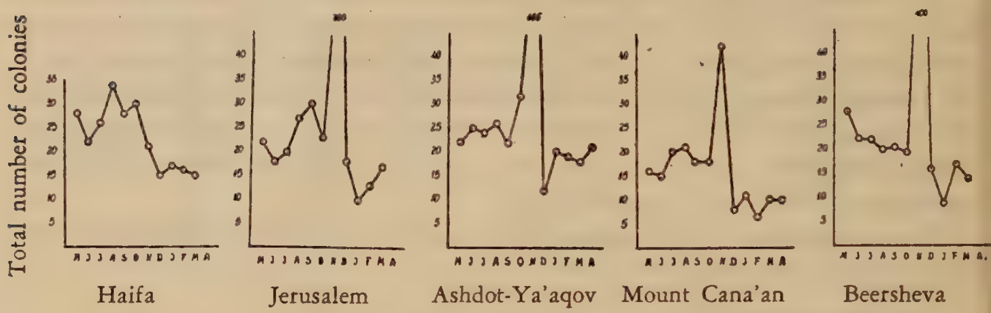


Figure 3

Annual distribution of air-borne fungi in 5 localities in Israel (Monthly averages) (May 1951 — April 1952).

Seasonal variation was found in all localities. In Beersheva, situated in the south, and further inland, seasonal variation was less marked. The number of colonies in all stations, with the exception of Mount Cana'an, during summer and autumn averaged 20-30 per plate. During the winter months the average was 12-18. On Mount Cana'an the average number of colonies throughout the year was only 15-20, and in winter the number dropped to 8-10.

In some localities unusually high peaks were recorded in November. These were correlated with strong winds at the time of exposure.

C. *Distribution of genera*

The distribution of genera over the seasons was as follows :

1. *Hormodendrum.* This was the ubiquitous air-borne fungus which constituted 40% of the total catches in Tel-Aviv and 35-65% of the total in other stations. It showed a distinct seasonal variation in most stations. The curve representing the total number of colonies is very similar to the curve for *Hormodendrum* alone, and the high peaks in the total number of fungi were caused mostly by the increase in *Hormodendrum* spores, which sometimes reached up to 90% of the total number of fungi.

2. *Pencillium. Pencillium* constituted 14% of the total number of colonies in Tel-Aviv and 5-14% in other stations. This genus failed to show noticeable seasonal differences in distribution.

3. *Aspergillus. Aspergillus* constituted 9% of the total in Tel-Aviv and 2.5-9% in other stations. Here again no noticeable seasonal variations were evident.

4. *Alternaria. Alternaria* constituted 10% of the total number in Tel-Aviv, and 6-11% in other stations, excluding Mount Cana'an where 18% of the total was found.

In Tel-Aviv no marked seasonal variation was found in the occurrence of *Alternaria.* On Mount Cana'an, however, this genus showed a clear seasonal variation, similar to that found for *Hormodendrum.*

5. *Miscellaneous fungi.* This group constituted 20% of the total number of colonies in Tel-Aviv and 13-29% in other stations. It included many genera, of which the most common were : *Stemphylium, Fusarium, Monilia, Mucor, Rhizopus, Epicoccum, Trichoderma, Botrytis, Helminthosporium, Pullularia, Stachybotrys, Phoma, Chaetomium, Torula,* etc. It is worth noting, that one or another fungus in this group is likely to appear suddenly in large numbers; for instance, spores of *Trichoderma lignorum* appeared in great numbers in April 1951; counts of the genus *Fusarium* were higher during 1950 than in the other years.

In this group unidentified fungi which developed only sterile mycelium are included.

6. *Actinomycetes.* Spores of this group made up to 8.5% of the total catches in Tel-Aviv and 2.5-14% in other stations. Their number varied with the season and was highest during summer.

7. *Yeasts.* Spores of yeasts appeared in considerable numbers. However this group was not investigated in this work.

II. SURVEYS OF AIR-BORNE FUNGI AT VARIOUS ALTITUDES AND OVER THE SEA

A. *Various altitudes over land*

Collections were made from an aeroplane on 9.6.1953 at 15 various altitudes up to 2000 metres. The weather was very clear and sunny, the temperature 24°C. Wind velocity at the airport (at sea level) was 3 miles per hour. The aeroplane flew at a constant speed of 70 miles per hour. At each of the 15 altitudes two plates were exposed parallel to the land surface; every exposure lasted 30 seconds, during which the aeroplane maintained constant altitude.

The following distribution of fungi was found (Figure 4) : At altitudes up to 300 metres there were large numbers of fungi, averaging 15.5 colonies per plate, as compared with an average of 5 colonies per plate at ground level where there was very little wind. At altitudes between 300 and 1000 metres, there were only few spores averaging 2.4 colonies per plate. Above 1000 metres spores occurred only rarely.

At all altitudes the majority of spores were those of *Hormodendrum.* Colonies of Actinomycetes were distributed in almost all altitudes up to 1750 metres. *Alternaria, Stemphylium* and *Penicillium* were found only in small numbers (1-2 colonies per plate) and appeared mostly up to 500 metres.

B. *Various distances from shore*

Spores were collected on shipboard, between Haifa and Crete (distance of about 600 miles) and back, during seven days.

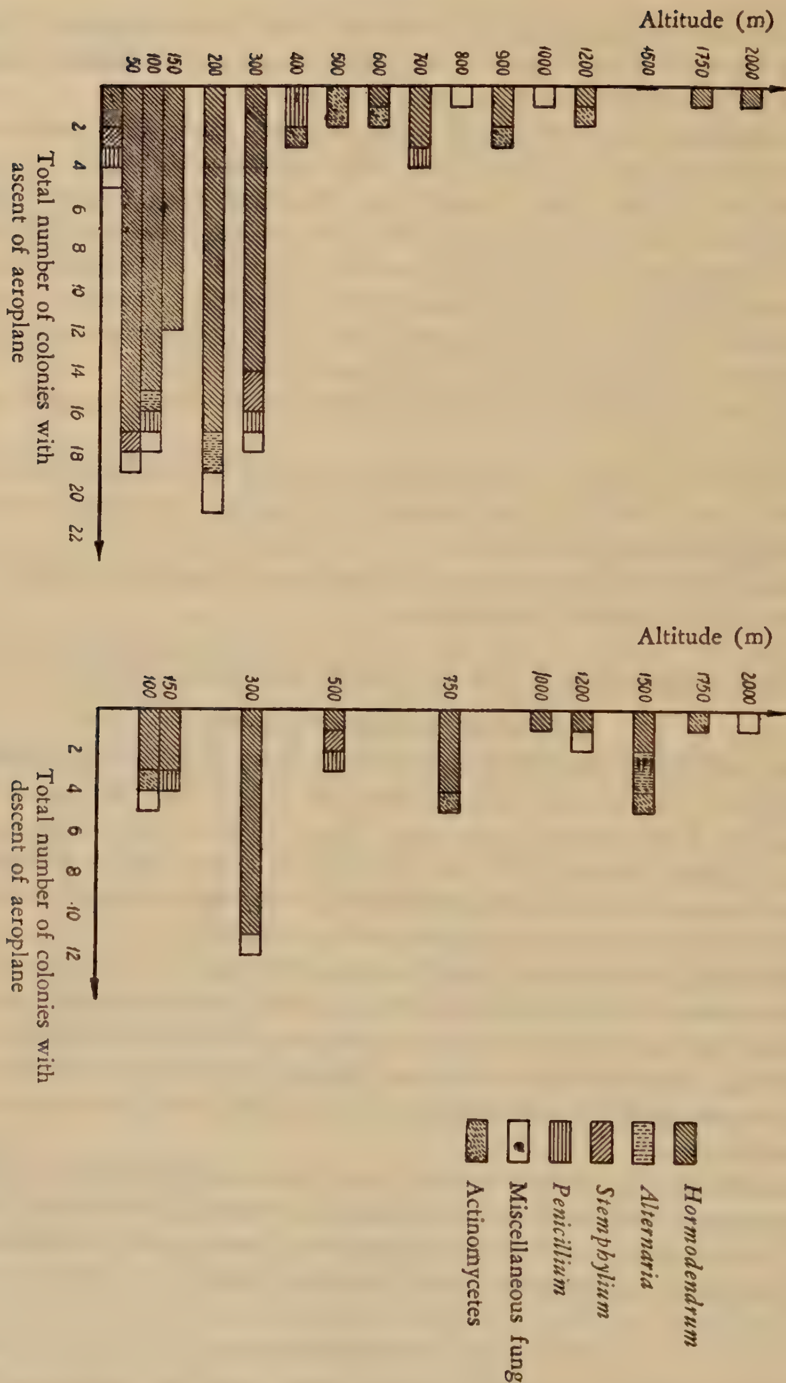


Figure 4
Distribution of air-borne fungi at various altitudes.

Collections were made, using the usual practice of exposing two plates simultaneously, at 0, 2, 5, 10, 20, 50, and 100 miles from the coast, and then at 100-mile intervals. On approaching Crete exposures were again made more frequently. It is, however, to be borne in mind that during the time of exposure the ship continued to sail, and that plates were exposed at various hours of day-time, according to the distance from shore.

As shown in Figure 5 there were no variations in meteorological conditions up to 20 miles from shore; the number of spores in the air decreased with the distance from shore to an average of only 2 colonies per plate, as compared with an average of 21 colonies found in the port. After 20 miles there were changes in wind velocity, and the stronger the wind, the greater the number of spores collected. In one case, about 20 miles from Crete, the number of colonies increased to 189 per plate, the majority being those of *Hormodendrum*. This was correlated with a strong NE wind of 17-21 knots. The temperature range for all exposures was from 25° to 29°C and did not bear any relation to variations in fungal counts.

The species found over the Mediterranean Sea were identical with those found over land. No area was found to be entirely free of air-borne spores.

LIST OF FUNGUS SPECIES COLLECTED

PHYCOMYCETES

Mucor spp., section *Racemosus*
Mucor hiemalis Wehmer
Rhizopus nigricans Ehrenberg

ASCOMYCETES

Chaetomium spp.
Pleospora spp., *P. herbarum* group

FUNGI IMPERFECTI

Phoma humicola Gilman et Abbott
Phoma spp.
Pestalotia versicolor Speg.
Geotrichum candidum Link
Monilia sitophila (Montagne) Saccardo
Monilia spp.
Cephalosporium curtipes Saccardo
Cephalosporium humicola Oudemans
Trichoderma lignorum (Tode) Harz
Aspergillus clavatus Desmazieres
Aspergillus nidulans (Eidam.) Winter
Aspergillus variecolor (Berk. et Br.) Thom et Raper
Hormodendrum cladosporioides (Fresenius) Saccardo
Hormodendrum hordei Bruhne
Helminthosporium sativum Pammel, King et Bake
Helminthosporium anomalum
Aspergillus ustus (Bain.) Thom et Church
Aspergillus sydowi (Bain. et Sart.) Thom et Church
Gilman et Abbott
Spondylocladium spp.
Aspergillus versicolor (Vuill.) Tiraboschi
Aspergillus terreus Thom
Aspergillus carneus (v. Tiegh.) Blochwitz
Aspergillus niger v. Tiegh.
Aspergillus wentii Wehmer
Aspergillus tamarii Kita
Aspergillus flavus Link
Aspergillus ochraceus Wilhelm
Penicillium decumbens Thom
Penicillium chrysogenum Thom
Penicillium digitatum Saccardo
Penicillium expansum Link
Penicillium italicum Wehmer
Penicillium spp., *P. purpurogenum* series
Sporotrichum roseum Link
Botrytis cinerea Pers.
Sepedonium xylogenum Saccardo
Verticillium spp.
Pullularia pullulans (de Bary) Berkhout
Hormiscium spp.
Torula spp.
Stachybotrys atra Corda
Stemphylium botryosum Wallroth
Alternaria tenuis Nees
Alternaria humicola Oudemans
Alternaria spp.
Graphium spp.
Fusarium spp.
Gilman et Abbott
Spondylocladium spp.
Epicoccum spp.
Epicoccum spp.

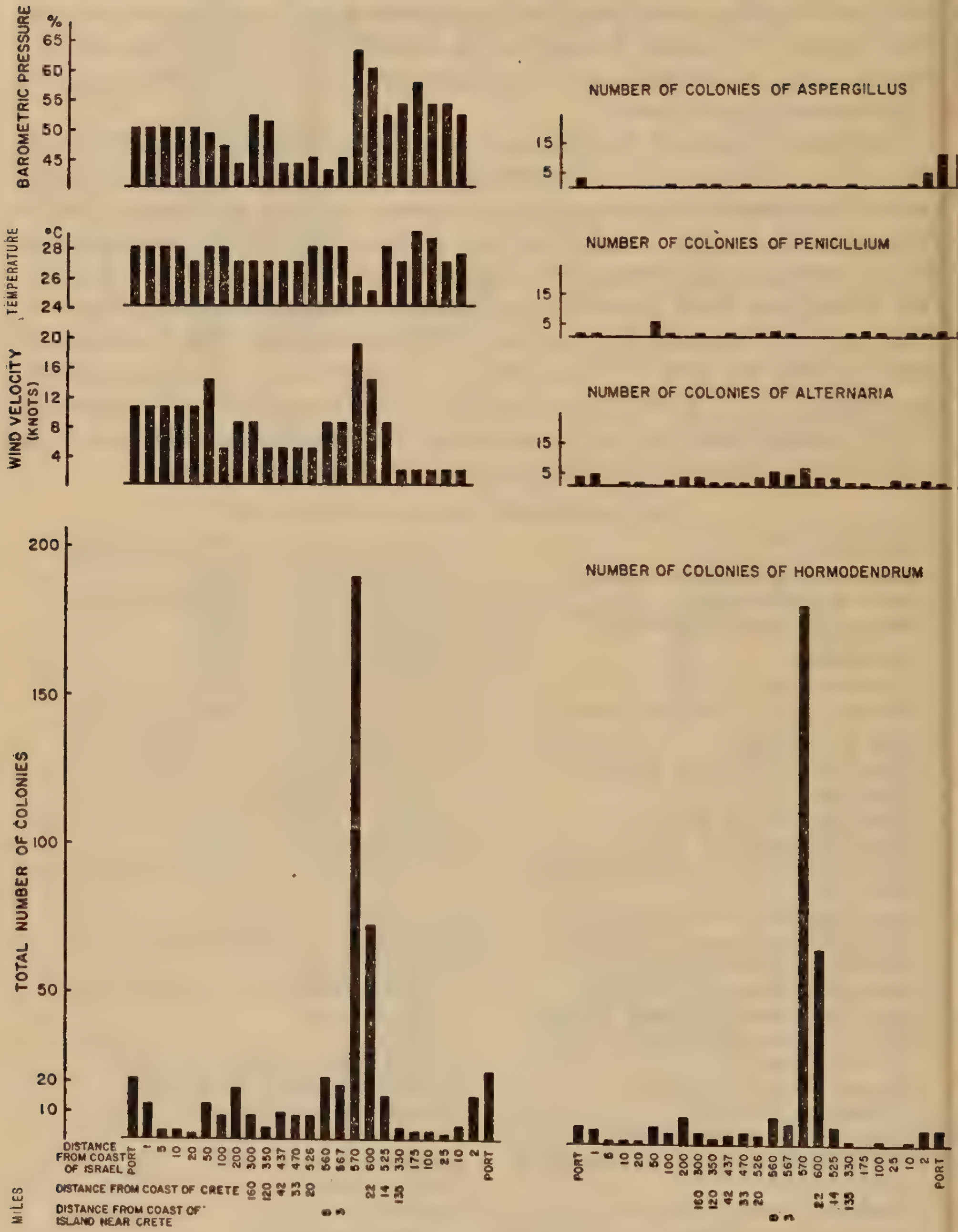


Figure 5
Distribution of air-borne fungi at various distances from shore.

DISCUSSION

A study on air-borne pollen and fungus spores in Tel-Aviv was conducted in 1951-52 and 1953 by Kessler (1953, 1954) using the slides method. The results are, therefore, not strictly comparable to our data obtained by culturing. There was, however, fair agreement concerning the seasonal variation of total numbers (lowest counts during January to March) and the prevalence of *Hormodendrum* and *Alternaria.* Kessler points out the common occurrence of rust and smut spores, which are readily observed on slides. On the other hand, he does not mention fungi, such as *Penicillium, Aspergillus* and other moulds, which can be distinguished only by culturing.

The *Hormodendrum* was found to be the predominating air-borne fungus in various countries. In many studies this fungus was identified as *Cladosporium.*

In the U.S.A. Feinberg and Little (1936) and Bernstein and Feinberg (1942) conducted studies and surveys of daily mould and spore content of the air in Chicago. Like in Israel, *Hormodendrum* and *Alternaria* were found to be the commonest air-borne fungi, followed by *Penicillium* and *Aspergillus.* Other studies conducted by Pratt (1938) in Boston, Pennington (1940) at Nashville (Tennessee), and Cohen (1942) in Buffalo, N.Y., also showed *Hormodendrum* and *Alternaria* to be the predominating fungi in the air.

In Rio-de-Janeiro, Passarelli, Miranda and Castro (1949) found *Penicillium, Hormodendrum* and *Aspergillus* to be the commonest fungi, while *Alternaria* was found rarely.

In Europe, Hyde and Williams (1949) found at Cardiff, Britain, that *Cladosporium* made up 51% of the total number of fungi, followed by *Penicillium* (13%) and *Pullularia* (4%). Ainsworth (1952) in London found *Cladosporium* to be predominating. Richards (1956) reported *Cladosporium* to be the commonest fungus in the air in nine stations in Britain, making up 35-88% of the total catch, followed by *Pullularia* and *Penicillium.* Rennerfelt (1947), near Stockholm, and Nilsby (1949), at Orebro in Sweden, found *Hormodendrum* to be predominating, followed by *Penicillium* and *Pullularia.* Flensborg and Samsöe-Jensen (1950) in Copenhagen, found that *Hormodendrum* colonies constitute more than 50% of the total, followed by *Penicillium* and *Pullularia.* Vallery-Radot, Halpern, Secretain and Domart (1950) in Paris found *Cladosporium* to be commonest, followed by *Alternaria* and *Penicillium.* Volterrani (1954) in Turin found *Cladosporium* to be the prevalent air-borne fungus, followed by *Epicoccum* and *Alternaria.*

In New Zealand, Dye and Vernon (1952) found *Cladosporium* followed by *Stemphylium, Alternaria* and *Penicillium* to be the predominating fungi in the air.

Thus there is a remarkable measure of agreement in the qualitative composition of the spore content of the air as determined by studies in widely distant parts of the globe.

Quantitatively there are sometimes considerable differences in spore counts in various localities. Thus, Bernstein and Feinberg (1942) in Chicago found *Alternaria* to constitute above 30% of the total, while in Israel we found this fungus to approximate 10% only. Hyde and Williams (1949) and Richards (1956) in Britain, reported *Alternaria* to be among the less frequent fungi, and in Sweden and Denmark Nilsby (1949), and Flensborg and Samsöe-Jensen (1950) also reported *Alternaria* as a rare fungus. On the other hand, *Pullularia* was reported in both Britain and Sweden as a most prevalent air-borne fungus. This fungus was only infrequently found in Israel.

ACKNOWLEDGEMENT

I wish to express my profound thanks to Prof. T. Rayss of the Hebrew University of Jerusalem for her kind guidance and ready encouragement throughout the course of this work. My sincere gratitude is also due to the Israeli Institute for Biological Research in whose laboratories the major part of this work was carried out.

REFERENCES

1. Ainsworth, G. C., 1952, The incidence of airborne *Cladosporium* spores in the London region, *J. gen. Microbiol.*, 7, 358-361.
2. Bernstein, T. B. and Feinberg, S. M., 1942, Airborne fungus spores: a five-year survey of daily mold spore content of Chicago air, *J. Allergy, 13,* 231-241.
3. Cohen, V. L., 1942, The content of fungus spores in the air of Buffalo, New-York, Abs. in *J. Bact., 1,* 115-116.
4. Dye, M. H. and Vernon, T. R., 1952, Airborne mould spores, *N.Z.J. Sci. Tech., Sect. B., 34,* 118-127.
5. Feinberg, S. M. and Little, H. T., 1936, Studies on the relation of microorganisms to allergy: III. A year's survey of daily mold spore content of the air, *J. Allergy, 7,* 149.
6. Flensborg, E. W. and Samsoe-Jensen, T., 1950, Studies in mould allergy, mould spore counts in Copenhagen, *Acta allerg., 3,* 49-65.
6a. Gregory, P. H., 1952, Spore content of the atmosphere near the ground, *Nature Lond., 170,* 475-477.
7. Hyde, H. A. and Williams, D. A., 1949, A census of mould spores in the atmosphere, *Nature, Lond., 164,* 668-669.
8. Kessler, A., 1953, Survey of airborne pollen and fungus spores in Israel, 1951-1952, *Ann. Allergy, 11,* 322-328,
9. Kessler, A., 1954, Survey of airborne pollen and mold spores in Israel, 1953, *Ann. Allergy, 12,* 261-262.
10. Nilsby, I., 1949, Allergy to moulds in Sweden, *Acta allerg., 2,* 57-90.
11. Passarelli, N., Miranda, M. P. and Castro, C., 1949, A study of the incidence of air-borne fungi in the city of Rio de Janeiro, *Ann. Allergy, 7,* 334-338.
12. Pennington, E. S., 1940, A study of the incidence of air-borne molds and skin sensitivity to molds, *Sth. med. J., 33,* 931-938.
12a. Pratt, H. N., 1938, Mold spore content of the air in Boston with reference to atopic sensitivity, *J. Pediat., 14,* 234-241.
13. Rennerfelt, E., 1947, Some investigations on the fungus spore content of the air, *Svensk. bot. Tidskr., 41,* 283-294.
14. Richards, M., 1956, A census of mould spores in the air over Britain in 1952, *Trans. Brit. mycol. Soc., 39,* 431-441.
15. Vallery-Radot, P., Halpern, B. N., Secretain, A. et Domart, A., 1950, Etude de la nature et de la densité de la flore mycologique dans l'atmosphère de Paris durant l'année 1948, *Acta allerg., 3,* 179-197.
16. Volterrani, O., 1954, Allergia da spore fungine, *Folia allerg., 1,* 75-90.

Rhus pentaphylla Desf., a first record from the Eastern Mediterranean

At Rosh ha-Niqra, on the Israel—Lebanon frontier, there have recently been found several spiny shrubs of *Rhus* (leg. Lorch, IV. 1957) of a species not known so far for the Eastern Mediterranean. They were found growing on a rocky slope some 30 m above sea level close to the coast-line. In summer, they lost almost all their leaves, as a result of their free exposure to the steady and rather strong winds which blew from the sea.

Comparison with material at the Kew Herbarium showed these shrubs to be indistinguishable from *Rhus pentaphylla* Desf. (Fl. atl. i, 267 tab. 77; 1798). This record, together with a previously undetermined specimen at the Herbarium of The Hebrew University, collected north of Haifa, by Leinkram, extend the known area of this species from Sicily — until now its most easterly record — to the eastern shore of the Mediterranean.

R. pentaphylla, the only species of this large genus with digitate leaves, is related to *Rhus oxyacanthoides* Dum. and to other members of the section Gerontogae Engler, represented in Africa, the Mediterranean region and Eastern India.

J. Lorch
Department of Botany,
The Hebrew University of Jerusalem

Received August 13, 1958.

Investigations in the germination and respiration of pollen of *Pinus canariensis*

Long-term investigations of pollen germination in suitable media are made possible by the use of antibiotica, such as chloromycetin and statomycin, which inhibit the development of a bacterial flora. Streptomycin inhibits the uptake of sugar from the medium by the pollen.

Pollen grains of *Pinus canariensis* do not germinate in distilled water and show only a limited germination (percentage of germination and length of pollen tubes) in urea or glycerol solutions. The germination of pollen in glycerol is greatly enhanced by potassium.

The pollen grains germinate well in sucrose solutions (0.3-0.5M) at pH=2.5-5.0. The optimum of germination (about 75%) occurs in 0.3M sucrose at pH = 2.7 and 26 - 28°C. The optimum pH value of germination, when fixed by diluted hydrochloric acid, is very sharply pronounced; germination completely stops at pH = 2.2 and falls sharply at pH higher than 3.0. Addition of potassium to the sugar medium causes an extension of the pH range of germination up to pH = 7.0 and increases the maximal germination up to 90%. Citrate and phthalate buffers cause a slight shift of the germination optimum to higher pH values (3.0 - 3.5), while phosphate practically suppresses germination.

Ultra-violet irradiation of pollen greatly enhances germination, causing an extension of the range of optimal germination (80-90%) up to pH = 8.0 at least.

Pollen of *Pinus canariensis* shows a strong respiration in sucrose solutions under all conditions of germination, and a weaker, but still considerable, respiration rate at higher pH values which inhibit germination. Potassium does not influence respiration. Ultra-violet irradiation greatly increases respiration at higher pH values (up to pH = 8.0 at least).

The uptake of sugar from the medium by respirating and germinating pollen is associated in the initial stage with an uptake of potassium which is released in the later stages of sugar metabolism.

E. Havivi and J. Leibowitz,
Department of Biological Chemistry,
The Hebrew University of Jerusalem

Received August 15, 1958.

PROCEEDINGS OF THE FIFTH MEETING OF THE ISRAEL GENETICS SOCIETY

Germination inhibition in castor beans.

DAN ATSMON, *The Weizmann Institute of Science, Rehovot*

Slow, ununiform and late germination of the variety Afruri is associated with two other traits: 1) Early and extensive sclerification of the capsule tissue, controlled by a single dominant gene, and 2) extremely small seeds (about a third of the size found in other varieties).

In crosses between Afruri and a normal variety, it was found that there is a significant difference in the rate of germination between the 2 types of F_1 seeds derived from reciprocal crosses. Those seeds in which the normal variety was the female parent, germinated much faster than seeds of the same genetic make-up which were collected from the Afruri plants. It is suggested that the maternal tissues in which seeds develop, influence decisively the germinability of the seeds. In addition to this maternal effect, the genotype of the male parent also influences seed germinability, but less so. This component of germinability which is influenced by the genetic make-up of the seed itself, is probably under multi-factorial control.

It has been demonstrated that the size of the ripe seed is related to germinability. Seeds below a certain size limit, show reduced germinability when compared to larger seeds collected from the same plant.

The inheritance of seed size in this material appears to be quantitatively determined. In addition to this, the sclerification of the capsule coat limits seed size, i.e. strong sclerification of capsule wall (small seed) vs. weak sclerification of capsule wall (larger seed).

Attemps are being made to control the sclerification process artificially in order to determine whether such treatment will have some influence on seed size and by this — on the germinability.

An analysis of a case of hybrid vigour in the castor bean plant.

HAVA STEIN, *The Weizmann Institute of Science, Rehovot*

The existence of hybrid vigour in the castor bean plant was first reported some 40 years ago, and today the use of F_1 hybrid seed for commercial plantings is continuously increasing. The castor bean plant is a facultative cross pollinator, but selfings through 6-7 generations did not result in any inbreeding depression.

In the F_1 hybrid between the pure lines Pure Red and Pure Green a significant yield increment (106%) over the higher yielding was found together with a marked increase in vegetative vigour. The changes in the three components of yield were examined. These components are: First — number of seeds per raceme; second — number of racemes per plant; third — weight of 100 seeds. Only in the first component — number of seeds per raceme — did the hybrid exceed the better parent (by 58%). This increment pobably is an expression of the increase in vegetative vigour. As to the second component, the hybrid came very close to the parents' arithmetic mean; with regard to the third component, it came close to the parents' geometric mean. Although the hybrid does not surpass its parents in either of these components when they are considered separately, it does exceed both parents in the product of these components (number of racemes per plants × 100 seeds' weight, and it is this product, of course, which contributes towards total yield. This finding, which will be referred to as the "product effect", can be explained entirely on mathematical

grounds, not requiring any biological changes. Utilising this effect, it is possible to obtain an increment in yield without increased vegetative development. Even though in the present case the "product effect" is accompanied by "physiological hetorosis", it should prove possible to find parent combinations the offsprings of which show the "product effect" only. Such hybrids are desirable, because plants producing a bigger crop, without forming extra vegetative mass are more efficient producers than heterotic hybrids.

Pachytene studies in the castor oil plant

KARL M. JACOB, *The Weizmann Institute of Science, Rehovot*

Each of the 10 chromosome pairs of *Ricinus communis* L. was shown to be morphologically distinct, at pachytene of meiosis. On basis of the chromomere pattern of the deeply staining chromatic zone and the position of the nonstaining centromere region within this zone, a chromosome map has been prepared. This pachytene map provides a diagrammatic description of each the chromosomes. The relative chromosome lengths, arm ratios, and lengths of the lightly staining achromatic zones, have been included in the map but are less useful in identifying individual chromosomes.

At pachytene, approximately 35% of the analyzable cells of *Ricinus,* variety Gamadon, exhibit H — and cross-shaped configurations of four chromosomes. Such "interchromosomal associations" involving chromosome E and G occur in about 19% of the analyzable cells. The centromeres of chromosomes E and G assume a central position in most of these configurations.

Interchromosomal associations which are also found at diakinesis and metaphase I, consist of true configurations of four chromosomes, as well as of loose associations of pairs. The phenomenon of secondary association at metaphase I and later meiotic stages, which has been reported for *Ricinus* by earlier investigators has been reexamined in light of the pachytene data of chromosomes E and G. The role of centric fusion and the possible exchange of portions of pairing strands between chromosomes which are presumed to be largely or entirely non-homologous, have been discussed.

Interspecific relationships in the genus *Carthamus*

AMRAM ASHRI, *Faculty of Agriculture, The Hebrew University, Rehovot*

This work was done by the author with the guidance of Dr. P. F. knowles. The genus *Carthamus* L. is found around the Mediterranean Sea, in Western Asia and in the Nile Valley. It contains about 25 valid species, one of which is cultivated (safflower). In a study conducted with eleven species, there were found two basic numbers in the genus, X = 10, 12. On the basis of chromosome numbers four sections may be distinguished in the genus:

Section I: 12 pairs, contains *C. arborescens* L., *C. caeruleus* L., *C. oxyacantha* M. B., *C. palestinus* Eig, *C. tinctorius* L. (cultivated).

Section II: 10 pairs, with *C. alexandrinus* (Boiss.) Bornm., *C. glaucus* M. B., *C. syriacus* Boiss.) Dinsm., *C. tenuis* (Boiss.) Bornm.

Section III: 22 pairs. Only *C. lanatus* L.

Section IV: 32 pairs. Only *C. boeticus* (Boiss. & Reut.) Nym.

The interspecific relationships within and between sections, as well as the origin of several species, were discussed.

Inheritance of the sex forms in *Cucumis sativus*

ESRA GALUN, *The Weizmann Institute of Science, Rehovot*

The results of previous investigations showed that the flowering pattern of the cucumber plant could be divided into three phases: — male (staminate flowes), mixed (staminate

and pistillate flowers) and female (pistillate flowers) phase. In monoecious plants, only the first and second phases occur (third — very rare) and in gynoecious plants, only the third, and occasionally, the second, occur. In the progeny of crossing between monoecious and gynoecious plants, the number of gynoecious ones was always smaller than expected according to the "one dominant gene" hypothesis. It could be shown that this resulted from some gynoecious plants in which the second phase was longer than usual and therefore resembled monoecious ones. It was further found that when in such crosses the monoecious parent has a strong male tendency, the heterozygotes have even the first phase, and third phase occurs very late in the development of the plant. Therefore, they first look like monoecious (recessive) types. The assumption that the effect of the factor for "femaleness" expresses itself by shifting all the phases towards the base of the plant was proven by the introduction of this factor into an andromonoecious type which resulted in a hermaphrodite plant, which was not known in the species *C. sativus* and is a new, true breeding sex type. Some evolutionary aspects concerning the evolution of dioecious species from monoecious ones based on a female-type mutation were discussed.

BOOK REVIEW

MALATTIE DELLE PIANTE, VINCENZO RIVERA, 583 pp. with 219 fig. and 58 tables, Amatrice (Rietti), 1943 and 1954. (Italian).

The first volume of Prof. Rivera's manual on plant diseases published in 1943, drew much attention. This book was unique in form, not resembling any other book on plant pathology at that time. It dealt with general principles and with diseases caused by viruses and bacteria. The second volume was scheduled to follow immediately, but unfortunately there was a delay when Prof. Rivera answered the call of his nation to serve in the Italian Parliament as a defender of agriculture and a champion of science. The second volume, published in 1954, covers fungus diseases and gives an extensive section to ecology and control measures. It is now appropriate to view this work as a whole and to evaluate it. This work brings forth innovations in phytopathological didactics. Most authors on phytopathology present in their discussions of plant diseases a collection of details on parasites and pay very little attention to pathobiological behaviour of the diseased plant itself. Prof. Rivera, gives prominence to the host plant in the description of the disease, "Symptomology and physiopathological behaviour of the host plant must serve as the basis of phytopathological teachings". Etiology has only to serve as an expedient measure to explain the pathogenesis. For adequate understanding of control measures, a thorough knowledge of the disease stages of the host plant is a prerequisite. Therefore only by this means can the vast amount of dry material in phytopathology become palatable to the student.

The disposition of the host plant is the chief principle upon which Prof. Rivera's system is established. On the basis of 25 years of teaching, the author has become convinced of the correctness of his approach. This principle is not new. Paul Sorauer first developed it in 1878. Prof. Rivera's contribution is the application of this principle to teaching phytopathology and showing how it may be put into effect in didactic practice.

Until the appearance of Prof. Rivera's book, one of two methods was commonly used in manuals on phytopathology: (a) according to the taxonomy of the pathogen or (b) according to the taxonomy of the host plant. The author feels that these are too artificial and that they cause unnecessary repetitions, thus making heavy demands on the memory and endurance of the student. From his and others' experience the author became convinced that the student was not interested in dry and unrelated details, but merely memorized them to pass an examination and thereafter promptly forgot them. According to both preceding systems no organic relationship exists between the descriptions and the disease. The inter-related morbid symptoms are, by force of these systems, spread troughout the various divisions of the taxonomic classification and thus one must continually repeat the same material.

The new pedagogical principle in which Prof. Rivera arranges the pathological material is the *"comparative method of pathological symptoms and grouping them together"*. The author divides all the phytopathological phenomena into three categories: (a) plant diseases where pathogens cause deviations from normal growth inducing mal-formation, i.e. galls, tumours, etc.; (b) plant diseases where pathogens interfere with the normal metabolic functions of the plant, i.e. trachaeomycoses and virus yellows; and (c) diseases in which toxic exudates of pathogens damage limited areas, i.e. necrotic spots in leaves and fruit.

Within each of the categories a general introduction and enumeration of the various major diseases is presented. In the introduction all the important data are summarized in a detailed and critical manner dealing with physiopathology and symptomology. The enumeration of the important plant diseases which follows the introduction contains only the etiological

history of each plant. The new method of a discussion of a symptomology and physiopathology in the introduction makes the later repetition of this material in connection with each disease superfluous. At the end of each category follows a section in which adequate control measures common to the diseases of that category are presented. Since plant diseases are caused by three types of pathogens, virus, bacteria and fungi, each category is similarly sub-divided. The great advantages of the author's sub-divisions of the phytopathological material are: (a) The diseased host plant is paramount in his descriptions and not the usually hidden pathogen; (b) a whole series of diseases which have common symptoms are treated as a phytopathological unit, thus each disease need not be elaborately described individually; (c) repeating of control measures for each individual disease becomes unnecessary because they were already discussed in the section on control measure for the whole category; and (d) the material is thus presented to the reader in a short, concentrated and well organized form which is readily absorbed and retained, especially by the student.

The author produced a very desirable book. Without doubt this was due to his new approach. The beautiful style of the author's writing makes very easy and enjoyable reading. The book displays the characteristic dynamic emotionalism of the Italian scholar when he presents new ideas. The lightness and ease of reading in no way diminishes the thorough and deep coverage of the subject material of the book. Prof. Rivera has succeeded in integrating in his book all the phytopathological research results known at that time. The lack of the most recent developments in the field of phytopathology does not impair the pedagogical goals which the author completely achieved.

Prof. Rivera's book received a personal touch with the inclusion of many of the results of his own personal contributions to the field of phytopathology, his advancements in radiology, tumour research, and ecological control (Roselinia). Perhaps the space dedicated to radiology is too extensive. The author, in my opinion, should have complemented his citations of sources with a more adequate bibliography. The author was consistent in that he did not want to fatigue his reader and also in that he did not turn his book into a compendium. In my opinion a bibliography would have stimulated a reader to further study of phytopathology were it presented to him in so attractive a book. The few criticisms do not diminish from the great achievement of Prof. Rivera's book, which is unique in its kind, presents didactic originality and scientific thoroughness. It is a book which attracts the investigator, teacher and student. This book should be translated to a more widely known language in order to be made available to a larger number of phytopathologists.

I. Reichert
Agricultural Research Station, Rehovot

• Volume 6D, 1957—1958

BULLETIN OF THE RESEARCH COUNCIL OF ISRAEL

Section D
BOTANY

Bull. Res. Counc. of Israel. D. Bot.

Continuing the activities of the
Palestine Journal of Botany,
Jerusalem and Rehovot Series

INDEX

TO

VOLUME 6D

The Weizmann Science Press of Israel • Jerusalem ירושלים • מוסד ויצמן לפרסומים במדעי הטבע ובטכנולוגיה בישראל •

BULLETIN OF THE RESEARCH COUNCIL OF ISRAEL

MIRIAM BALABAN
Editor

Orders in America should be addressed to Interscience Publishers Inc., New York, N. Y., and in England and Europe to Wm. Dawson & Sons, Ltd., Cannon House, Macklin Street, London, W. C. 2, directly or through booksellers.

Annual subscription per section (four issues): IL. 6.000 ($ 6.00, £ 2.20) Single copy IL. 1.500 ($ 1.50, 12s.)

Manuscripts should be addressed: The Editor, The Weizmann Science Press of Israel, P. O. B. 801, Jerusalem, 33 King George Ave. Telephone 62844

NOTICE TO CONTRIBUTORS

Contributors to the *Bulletin of the Research Council of Israel* should conform to the following recommendations of the editors of this journal in preparing manuscripts for the press.

Contributions must be original and should not have been published previously. When a paper has been accepted for publication, the author(s) may not publish it elsewhere unless permission is received from the Editor of this journal.

Papers may be submitted in English and in French.

MANUSCRIPT

General

Papers should be written as concisely as possible. MSS should be typewritten on one side only and double-spaced, with side margins not less than 2.5 cm wide. Pages, including those containing illustrations, references or tables, should be numbered.

The Editor reserves the right to return a MS to the author for retyping or any alterations. Authors should retain copies of their MS.

Spelling

Spelling should be based on the Oxford Dictionary and should be consistent throughout the paper. Geographic and proper names in particular should be checked for approved forms of spelling or transliteration.

Indications

Greek letters should be indicated in a legend preceding the MS, as well as by a pencil note in the margin on first appearance in the text.

When there is any room for confusion of symbols, they should be carefully differentiated, e.g. the letter "l" and the figure "1"; "O" and "0".

Abbreviations

Titles of journals should be abbreviated according to the *World List of Scientific Periodicals.*

Abstract

Every paper must be accompanied by a brief but comprehensive abstract. Although the length of the abstract is left to the discretion of the author, 3% of the total length of the paper is suggested.

References

In Sections A and C, and in Letters to the Editor in all Sections, references are to be cited in the text by number, e.g., ... Taylor[3] ... and are to be arranged in the order of appearance.

In Sections B, D, E, and G, the references are to be cited in the text by the author's name and date of publication in parentheses, e.g., ... (Taylor 1932).... If the author's name is already mentioned in the text, then the year only appears in the parenthesis, e.g., ... found by Taylor (1932).... The references in these Sections are to be arranged in alphabetical order.

In Section F, references are to be cited in the text by number in square brackets, e.g.,... Taylor [3]... and are to be arranged in alphabetical order.

The following form should be used:

3. Taylor, G. I., 1932, *Proc. roy. Soc.*, A138, 41.

Book references should be prepared according to the following form:

4. Jackson, F., 1930, *Thermodynamics*, 4th ed., Wiley, New York

TYPOGRAPHY

In all matters of typography the form adopted in this issue should be followed. Particular attention should be given to position (of symbols, headings, etc.) and type specification.

ILLUSTRATIONS

Illustrations should be sent in a state suitable for direct photographic reproduction. Line drawings should be drawn in large scale with India ink on white drawing paper, bristol board, tracing paper, blue linen, or blue-lined graph paper. If the lettering cannot be drawn neatly by the author, he should indicate it in pencil for the guidance of the draftsman. Possible photographic reduction should be carefully considered when lettering and in other details.

Half-tone photographs should be on glossy contrast paper.

Illustrations should be mounted on separate sheets of paper on which the caption and figure number is typed. Each drawing and photograph should be identified on the back with the author's name and figure number.

The place in which the figure is to appear should be indicated in the margin of the MS.

PROOFS

Authors making revisions in proofs will be required to bear the costs thereof. Proofs should be returned to the Editor within 24 hours, otherwise no responsibility is assumed for the corrections of the author.

REPRINTS

Reprints may be ordered at the time the proof is returned. A table designating the cost of reprints may be obtained on request.

INDEX

TO

VOLUME 6D

CONTENTS

Number 1, August 1957

Number 2, January 1958

AUTHOR INDEX

SUBJECT INDEX

CORRIGENDA

Section D, Botany. Volume 6. Number 1

Contents page 1 : *for* true relationship *read* time relationship

Section D, Botany. Volume 6. Number 3

Contents page 1 : *for* true relationship *read* time relationship

p. 155, l. 21 : in Table III : *for* 1957 *read* 5927

p. 158, l. 6 : *for* Appler Immune *read* Appler Very susceptible

7 : *for* Bond Very susceptible *read* Bond Immune

p. 188, l. 21 : *for* molar concentration *read* osmotic values

יוצא לאור ע״י
מוסד ויצמן לפרסומים במדעי הטבע ובטכנולוגיה בישראל
המועצה המדעית לישראל - משרד החנוך והתרבות - האוניברסיטה העברית בירושלים
הטכניון — מכון טכנולוגי לישראל - מכון ויצמן למדע - מוסד ביאליק

Published by
THE WEIZMANN SCIENCE PRESS OF ISRAEL
Research Council of Israel, Ministry of Education and Culture
The Hebrew University of Jerusalem, Technion—Israel Institute of Technology
The Weizmann Institute of Science, Bialik Institute

Printed in Israel
Printing Press Gesher, Jerusalem

WSP/1000/10.58